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SIMULATING CLOTHING AND TEXTILE  
OPERATIONS AT THE DEFENSE  
LOGISTICS AGENCY  
VOLUME I: NARRATIVE DESCRIPTION

Report DL703R1

January 1989

Robert C. Kline  
Christopher H. Hanks

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LOGISTICS MANAGEMENT INSTITUTE  
6400 Goldsboro Road  
Bethesda, Maryland 20817-5886

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## PREFACE

This report is published in two volumes. Volume I is a narrative description of the clothing and textiles (C&T) simulation system, which includes the C&T simulation itself, a "capture" program for preparing input data, and an analytic inventory model for computing variable C&T safety levels.

Volume II presents a listing of the PC SIMSCRIPT II.5 source code for each of the three parts of the system, alphabetical listings and brief descriptions of each procedure, and outline descriptions of the flow and interactions among procedures.



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**Executive Summary****SIMULATING CLOTHING AND TEXTILE OPERATIONS  
AT THE DEFENSE LOGISTICS AGENCY**

→ This report is

→ To help evaluate new ideas for reducing costs and improving supply performance, we have created a simulation model of clothing and textile (C&T) operations at the Defense Logistics Agency (DLA). DLA's Clothing and Textiles Directorate at the Defense Personnel Support Center in Philadelphia serves as the wholesale manager in DoD for roughly 30,000 different apparel and equipment items worn and used by U.S. Service personnel. The C&T Directorate sells and replenishes more than \$1.0 billion worth of materiel each year and maintains from \$1.5 billion to \$2.0 billion in inventory at depots and warehouses worldwide.

The C&T simulation model now in use at both DLA Headquarters and the C&T Directorate enables inventory managers to project and evaluate the potential effects of new inventory policies and operating methods. It runs on DLA Zenith personal computers (PCs) and operates on C&T data extracted from standard DLA Supply Control Files. It provides estimates of how supply performance, inventory levels, and costs are affected by different operating policies and procedures.

At its core, the model incorporates the basic operating rules and architecture necessary to simulate operations and interactions with customers and suppliers as they occur at any DLA Supply Center. For the C&T application, the model is specifically tailored to reflect unique aspects of the C&T business, such as multi-item procurement groups of items that come in different sizes, program-based estimates of future requirements, phased deliveries from suppliers, and the key C&T mission of providing strong supply support to Recruit Training Centers. (SLO) →

The model can be used to examine a variety of C&T policy options, including variable safety levels, matrix delivery schedules, and new procurement cycle controls. Because it is menu-driven, the model is accessible to a wide class of potential users – managers as well as analysts. Through the use of interactive queries and built-in switches, users can easily modify input data and change the

assumptions in a model run, thereby expanding the range of policy questions that can be examined without having to reprogram the model.

As the first in what could eventually become a family of PC-based simulations of DLA supply operations, the C&T simulation provides a tool to help DLA managers evaluate new C&T policies and ideas aimed at reducing costs and improving supply performance.

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## CHAPTER 1

### BACKGROUND

#### INTRODUCTION

The clothing and textiles (C&T) simulation is a personal computer (PC)-based model of inventory management in the Defense Logistics Agency's (DLA's) wholesale C&T business. Operating through its C&T Directorate at the Defense Personnel Support Center in Philadelphia, DLA serves as the wholesale manager in DoD for approximately 30,000 national stock numbers (NSNs) of apparel and equipment items worn and used by U.S. Service personnel.

Because different sizes of the same item have different NSNs, the C&T Directorate manages C&T items generically by procurement grouping code (PGC). The C&T simulation reflects this key aspect of the C&T business by simulating at the PGC level. That is, in a single run the model generates customer "demands," makes supplier "deliveries," and replenishes "inventory" for the entire set of items (all NSNs) in a PGC. A PGC is processed in accordance with C&T experience and practice, as reflected in C&T data.

In its basic operating mode, the model simulates activity for a single PGC, processing all the NSNs in the PGC simultaneously. To provide system-level results applicable to a collection of different PGCs, the model can process PGCs sequentially, one at a time, and accumulate results. Control options at the beginning of a run allow the user to specify whether more than one PGC is to be processed and how aggregate results are to be accumulated.

The model is designed for use by both analysts and managers to test new ideas on C&T operations. This report describes how the model works, how to run it, and how to interpret its output.

First-time users should read the report from the beginning. Others may go directly to Chapter 6 for step-by-step instructions on how to run the model — referring to other chapters as necessary for a review of model mechanics.

In this chapter, we review the nature of the C&T business and the background for the model's development. We address the question "Why simulation?" and look at some of the C&T policy questions that motivated the creation of the model.

In Chapter 2, we describe the input data the model requires to operate. These data include required item-level input data obtained from the DLA Standard Automated Materiel Management System (SAMMS), as well as control data and optional input data supplied interactively by the user prior to a run. Appendix A shows examples of input files.

In Chapter 3, we describe how the model works. We start with a general overview and follow that with specifics on the use of the input data, operating rules, order of operations, and probability distributions used to simulate different aspects of the C&T business.

In Chapter 4, we describe the model's output and how it is computed. The output of every run includes "trace" information that contains NSN-level results, a summary report at the PGC level, and if desired, a detailed record of all simulation events. The model also produces an Aggregate PGC Report, which can summarize the system-level results for a collection of PGCs processed sequentially or accumulate the results for several different runs on the same PGC. Graphic output reports are also described. Chapter 4 also covers the removal of the effects of the warm-up period, the determination of run lengths (related to sample size), and the calculation of confidence interval estimates for backorders. Appendix B contains examples of output reports.

In Chapter 5, we present verification and validation results. Verification involves testing model results to ensure that internal model logic and calculations are performing as intended. Validation is a comparison of model projections with real-world C&T data on backorders, supply availability rates, and asset positions to see how well the model is able to reflect real-world behavior.

In Chapter 6, we give step-by-step instructions for running the model on a DLA Zenith PC. The model requires a data link to permit downloading of SAMMS data (Special Supply Control Files and Management Policy Table 11 Reports) from a DLA mainframe computer to a PC. In Chapter 6, we also describe how to transfer input and output files to spreadsheet format (LOTUS 1-2-3) for further analysis if desired. Appendix C describes how to run the "capture" program for preparing input files

from downloaded SAMMS data. Appendix D describes an analytic variable safety level (VSL) model for computing VSL values prior to a run. Appendix E describes features of the dynamic graphics available in the C&T simulation displays.

In Chapter 7, we offer some observations and suggestions on several issues that have arisen in the course of the model's development. We discuss weaknesses and missing information in the input data available from SAMMS and ways those data might be improved in the future. We address possible problems arising from the way new C&T delivery schedules for controlling leadtimes are being programmed into SAMMS and suggest an alternative approach. Finally, we describe some important areas for further model development based on discussions of possible applications of the model in the future.

The C&T simulation model is programmed in PC SIMSCRIPT II.5, a programming language specifically designed for simulation on a PC. Volume II of this report contains a listing of the model's PC SIMSCRIPT code, descriptions of what each SIMSCRIPT routine does, and an outline showing how the different routines in the model relate to one another.

## THE C&T BUSINESS

Fundamentally, C&T operations are like those of any other DoD wholesale supplier: customers (retail-level supply outlets at military installations and bases) order materiel from C&T wholesale stocks to replenish their own retail stocks, which they use to serve *their* customers, who are the final consumers of the items. As their wholesale stocks are drawn down, C&T item managers monitor asset positions (on hand plus on order minus backorders) and decide when reorder points are breached, whether to order from suppliers to replenish their inventories, and how much to order. When orders are placed, they are for replenishment quantities that are sized based on economic and procurement considerations.

The system thus far can be described and analyzed with standard mathematical inventory models.<sup>1</sup> The nature of C&T items, however, and the way

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<sup>1</sup>Standard mathematical inventory models are analytic models that, in one form or another, solve the two fundamental problems of inventory management: when to order (the reorder point) and how much to order (the order quantity). Such models usually take the form of constrained optimization models that minimize ordering, holding, and penalty costs for a system of items, subject to a constraint on minimum acceptable supply performance.

C&T customers and suppliers interact with the C&T Directorate, combine to produce special operating characteristics that cannot be captured with standard models. Some other way to analyze C&T operations is needed. Simulation is a natural choice because it allows incorporation of special operating features without requiring the development of special mathematics.

The special features distinguishing C&T operations are the use of multi-item PGCs for management of sized items (e.g., shoes, clothing, outerwear); the use of troop strength and induction forecasts from the Services as the basis for projecting demand in the Program Oriented Item (POI) system;<sup>2</sup> and the special emphasis the C&T Directorate places on providing responsive supply support to Recruit Training Centers.

### WHY SIMULATION?

The C&T Directorate's use of multi-item PGCs is the compelling reason for the simulation approach. Within the C&T commodity, multi-item PGCs are used to manage the many different clothing and apparel items that come in different sizes. In a multi-item PGC, each different size has its own NSN, reorder point, and procurement cycle, but in most other respects the entire PGC is managed as a single item. For example, demand is forecasted for the generic item, using distributions ("size tariffs") to allocate demand by NSN. Also, in a multi-item PGC, when any one item (size) is ordered from a supplier, other items (sizes) can and often will be ordered as well – even if they are still some distance from their reorder points. This reordering policy is an unavoidable aspect of the wholesale C&T business because it reflects the way C&T manufacturers and suppliers generally do business: They deal in large orders, and large orders for sized items usually call for a mix of sizes.

The multi-item PGC aspect of C&T operations prevents the use of standard mathematical inventory models in analyzing even simple policy alternatives. Such

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<sup>2</sup>C&T manages about 30,000 different items (NSNs), which fall into four separate categories: POIs – about 8,500 items; demand-based items [Quarterly Forecasted Demand (QFD)] – about 11,000 items; Government-furnished materiel (GFM) – about 2,000 items; and new and numeric stockage objective (NSO) items – about 9,000 items. The C&T simulation treats POI and QFD but not GFM or new/NSO-type items. POI and QFD comprise approximately two-thirds of the total items managed by C&T, represent the bulk of C&T's dollar volume of sales, and are the items most affected by changes in DLA inventory management policies. The GFM program, while an important part of C&T's business, is not a key problem area according to C&T Directorate personnel. New/NSO-type items, while also important and certainly a source of potential problems, are by nature not amenable to analysis employing demand-driven inventory models.

standard models assume individual items are ordered only when at or near their reorder points and that item demand patterns are independent from one item to the next. Neither of those principles holds for a multi-item PGC. As a result, standard analytic models cannot reliably project how changes in replenishment and ordering policies will affect operations.

## C&T POLICY QUESTIONS

Given that simulation is to be the approach, we now turn to the particular C&T policy questions of interest. The issue motivating the development of the C&T simulation is the question of *variable safety levels*.

A "safety level" is the extra level of stock for an item — beyond that required to cover average demand in a leadtime — that protects against the variations that occur about the average. Currently, the C&T Directorate employs a fixed safety level in which each NSN in a PGC is assigned a safety level equal to expected demand over a fixed number of months. The number of months depends on the category of the PGC (e.g., the NSNs in PGCs for sized items issued to recruits are generally assigned 4.5 months of safety level). VSLs are safety levels that are allowed to vary from item to item, even within a PGC, depending on each item's characteristics in relation to other items in the system. VSLs are used by DLA and most other DoD supply organizations to maximize supply performance for a given investment in stock levels.

VSLs are computed using mathematical optimization methods. For C&T operations, the question is whether VSLs can improve supply performance and reduce inventory investment costs, given the special characteristics of the C&T business. The optimization techniques generally used to compute VSLs do not account for multi-item PGCs, for example, nor do they consider the effect of incremental deliveries. The first job for the C&T simulation, therefore, is to evaluate what would happen to C&T performance and costs if the fixed safety levels currently used for C&T items — safety levels set to cover a fixed number of months of demand — were to be replaced with VSLs computed essentially as they are for other DLA commodities. (A separate LMI briefing book, *Variable Safety Levels for Clothing and Textiles*, looks at this question.)

VSL is not the only issue the C&T simulation can address. New ordering cost and holding cost factors and new minimum and maximum cutoff values for

procurement cycles (order quantities) are being introduced for C&T items. New "matrix" delivery schemes are also being instituted to stabilize C&T leadtimes and reduce contractor/supplier delinquencies. Through the use of interactive queries and easy-to-modify input files, users can experiment with the simulation to determine the potential effects of these new policies.

In addition to various features for current C&T policy options, the simulation also makes it easy for users to experiment with the other basic factors that influence any inventory management enterprise. For example, switches in the model allow the user to turn on and adjust demand variability and leadtime variability. Users can also modify the input data for the model and many of the model's control parameters prior to a run. Together, these features make the model easy to use while at the same time give it the ability to address a variety of different questions.

Throughout, a major goal has been to deliver a model that is easy to use. Once input files are prepared (and edited if required by the application), a model run is set up by interactively responding to a short list of simple questions. The model then runs one PGC at a time and produces a standardized set of summary reports that can be examined to see how alternative management policies affect supply performance and costs.

## CHAPTER 2

### INPUT DATA

This chapter describes the information needed as input to the C&T simulation prior to a run. Some of that information consists of data from external sources required prior to any run; some is control information supplied interactively by the user; and some is optional information that does not have to be supplied but can be if the application requires it. The main focus of this chapter is on the input data that are required from external sources. Space requirements on a PC hard drive for simulation software and input data are given at the end of the chapter.

#### THREE KINDS OF INPUT

The input data needed to run the C&T simulation fall into three categories: required input data, control data, and optional data. Required input data are the basic data about the items to be simulated that must be present in two input files on the PC hard drive before a run can begin. These required data are obtained from two sources in the DLA SAMMS system: Special Supply Control File (SSCF) reports and Management Policy Table 11 (MPT011) reports. The SSCF report is produced by NSN and contains item-specific information; the MPT011 report is produced by PGC and contains information that applies to all the NSNs in a PGC as a group.

Control input data consist of the responses a user makes to the set of interactive queries that begin a run: What item(s) are to be simulated? Do you want demand variance? Leadtime variance? Different responses to these and other start-up queries enable a user to control and change how the model operates from one run to the next. This makes it possible to perform different analyses without having to reprogram the model. The role of control input is discussed in more detail in the next chapter.

Optional input data are those data that a user may either specify or defer to default values that are provided so that a simulation run can take place. In general, the more flexible a model is in terms of its ability to answer different questions, the more complicated it is to set up a run. The use of optional inputs in the C&T



simulation provides additional flexibility without complicating the basic model. The choices for optional input are discussed in more detail in the next chapter.

Once a user has selected the PGC or set of PGCs to be simulated and arranged for the SSCF and MPT011 reports for those items to be downloaded to a PC, the C&T simulation makes it easy to prepare, input, and keep track of all three kinds of data.

For SSCF data, the required input file is prepared by running a prewritten, SIMSCRIPT program (incorporated as part of the C&T simulation system) that "captures" what is needed from a downloaded SSCF report and prepares the required file. For MPT011 data, the required input file consists simply of downloaded MPT011 reports, which are read by a routine built into the simulation itself. Both required input files have standard names (see Chapter 6) and are accessed every time the model is run. The contents of both files are also included in output as part of the audit trail for a run.

The responses a user makes to the queries that begin every run are listed prior to the run and in output, again as part of the audit trail.

Optional data are entered through the use of five optional queries. The first optional query allows the use of VSLs in a run. Before exercising this option, a file of VSLs must be constructed with the C&T VSL model (see Appendix D). The second and third optional queries allow the use of modified input files that can contain "made-up" SSCF and MPT011 data, for users who want to experiment without overwriting actual data. The fourth optional query activates an Alternative Assumption File (see Appendix A, Exhibit A-4) that enables users to change various procurement cycle parameters, controls whether input data is reproduced in the output file, and allows users to shut off the requisition-generation logic in the model's demand-generation process. The fifth optional query allows the user to add graphic output, if desired, to the standard output tables of numerical results.

#### **SPECIAL SUPPLY CONTROL FILE DATA**

The SSCF report is an edited printout of SAMMS Supply Control File data for a given NSN. The collection of SSCF reports for the NSNs in a given PGC (together with PGC information in MPT011 Reports) contains the required information needed to simulate C&T inventory management for the PGC. The SSCF data are captured from the header section, the Demand/Returns Trailer (Trailer E), and the

Program Requirements Trailer (Trailer U) from the SSCF report for each NSN in the PGC. Exhibit A-1 in Appendix A shows an example of the Header section and Trailers E and U from an SSCF printout. The data elements in an SSCF Header section are referenced in Appendix F-450 of the DLA Manual (DLAM) 4140.2, *Supply Operations Manual*, Volume II, Part 3, June 1982. The data elements in Trailers E and U are defined in Appendices F-191 and F-149 of DLAM 4140.2.

To prepare the required SSCF input data file for the simulation, SSCF reports for each NSN in the PGC must be downloaded from a SAMMS mainframe to a PC. SSCF reports are normally produced in hard copy, but manual entry of the data in SSCF reports is not practical. For downloading to a PC, it is most convenient to transmit SSCF reports directly to the PC hard disk via a direct telecommunications link from the mainframe. LMI understands that such links are available both in Philadelphia and in the DLA Operations Research Office (DORO) in Richmond, Virginia. (Given that Management Support Offices at DLA Supply Centers use SSCF reports and that DLA has been acquiring PCs, it makes sense for DLA to have such a mainframe-to-PC capability even without the C&T application.) Alternative approaches are to write SSCF reports to tape on the mainframe and use an intermediate device [e.g., the DLA DMINS (Distributed Minicomputer System) or a tape reader] to read the tape and download the data to a PC.

Once SSCF reports are downloaded to the PC, a capture program that processes SSCF reports extracts the data needed from each SSCF report for each NSN in the PGC and formats them into a smaller file containing only the data the simulation needs to process the PGC. Exhibit A-2 in Appendix A is an example of what a captured SSCF data input file looks like for a PGC containing three NSNs.

Most of the data elements in the SSCF input file prepared by the capture program are identical with those in an SSCF report. Moving from left to right and top to bottom in a captured SSCF input file (see Exhibit A-2 in Appendix A for an example), data elements are defined as follows:

- *PROC.GR.CD*: Procurement Grouping Code for the NSN (see DLAM 4140.2, Appendices A-116 and B-149).
- *MAX.NSN*: Number of NSNs in the PGC (supplied by the capture program based on its internal count as it processes raw SSCF reports).
- *ITEM NAME*: Generic description of the item (e.g., shirt, man's).

- **FSC:** Federal Supply Class (four-digit number).
- **ICC:** Item Category Code (possible codes are 1, 2, B, or P; 1 = QFD, 2 = NSO, B = Insurance, P = POI. See DLAM 4140.2, Appendices A-87 and B-189).
- **ADM.LT:** Administrative leadtime (in days) for the NSN (see DLAM 4140.2, Appendix B-189).
- **STANDARD.PRICE:** Price charged to retail customers (see DLAM 4140.2, Chapter 48).
- **MAX.MONTH:** Number of months of forecasted demand (supplied by the capture program, based on its internal count of entries in the Program Requirements Trailer).
- **NSN:** Ordinal index of the list of NSNs within the PGC.
- **NIIN:** National Item Identification Number (FSC concatenated with NIIN is the NSN for the item).
- **PRO.LT:** Production leadtime (in days) for the NSN (see DLAM 4140.2, Appendix B-189).
- **VIP (1 = Y):** Very Important Program indicator (1 = yes) (controls whether requirements are computed monthly or quarterly in SAMMS; see DLAM 4140.2, Appendix B-188).
- **FIX.SAFE:** Fixed safety level in months of demand (applies to C&T items).
- **QFD:** Quarterly forecasted demand (see DLAM 4140.2, Appendix B-64).

*Note:* Some items in the POI program have additional demand sources not captured in POI program requirements forecasts. For such items, this QFD entry shows this additional forecasted demand. For "pure" QFD items not in the POI program, this entry contains all quarterly forecasted demand.

- **MAD:** Mean absolute deviation (a measure of monthly or quarterly forecast error in demand forecast; see DLAM 4140.2, Appendices F-450 and D-185, and Chapter 54).
- **OWRMRP:** Other War Reserve Materiel Requirements Protectable (see DLAM 4140.2, Appendix B-181).
- **ALPHA:** Regular alpha factor (demand forecast control factor; see DLAM 4140.2, Appendices F-450, F-262, and B-64). The alpha factor is an extremely important parameter, both in demand forecasting and in the calculation of stockage-level requirements. In SAMMS, the alpha factor is used to smooth demand forecasts for QFD items; to calculate MAD; and to convert MAD to MADLT (mean absolute deviation in leadtime), which

measures deviation in leadtime demand. The C&T simulation uses the alpha factor only to convert MAD to MADLT. It does so following the MAD Multiplier Formula Table in the SAMMS documentation. For demand forecasts and MAD, the simulation simply uses the forecast and MAD values from SSCF reports. The simulation does not redo the smoothing already done to obtain those data elements.

- **ARS:** Average requisition size for the NSN (computed by the capture program from quantity and frequency data in Demand/Returns Trailer).

*Note:* ARS refers to the average number of units requested on the requisitions submitted to the C&T inventory. In computing the ARS, the capture program considers only demands and not returns listed in the Demand/Returns Trailer. Also, for items indicated to have high nonrecurring demand, only the "applicable percentage" of demand (percentage of nonrecurring demand allowed to be counted as recurring) is used in computing the ARS.

- **PER.RTC.DEMAND:** Percent Recruit Training Center demand [percent of total projected demand in the Program Requirements Trailer that is associated with RTC program identification codes (PICs); computed by the capture program].

*Note:* The POI system at the C&T Directorate utilizes Service projections of inductions and troop strengths to estimate future demands. In making that estimate, it uses PICs (five-character alphanumeric codes) and size tariffs. Service forecasts are generated by PIC. Demands for different sizes (NSNs) within a PIC are projected by applying a relative frequency distribution of demand by size – the size tariff for the PIC – to the total projected demand for the PIC. Demand projections in the Program Requirements Trailer are by NSN and, therefore, reflect the application of the PIC size tariff implicitly. Explicit input of size tariff data, therefore, is not required by the C&T simulation. The PICs employed by C&T operations for the POI program are listed in Defense Personnel Support Center (DPSC)-T Local Procedure #R-28, Volume II, DLAM 4140.2, Appendix A-130a. The capture program classifies demand from "Initial Issue – Recruit" PICs as RTC demand. Initial issue PICs are those ending in the characters AA, AW, or GB. For example, the PIC AOMAA corresponds to Army, Male, Active (Recruit Input). References for the POI program and the PIC system are Chapter 25 and Appendices B-51, B-52, and B-53 of DLAM 4140.2. For "pure" QFD items not in the POI program, the RTC demand percentage is assumed to be zero in the C&T simulation.

- **CT REQUIREMENTS MATRIX:** 6×6 matrices (one for each NSN in the PGC) containing POI unit demand forecast for the NSN, summed across all PICs, by month for the next 36 months; assembled by the capture program from data in the SSCF Program Requirements Trailer.

*Note:* For pure QFD items not in the POI program, there is no C&T requirements matrix in the SSCF input file. Forecasted requirements for pure QFD items appear under the QFD data element listed earlier.

- **END.OF.PGC:** Marker indicating end of SSCF data for NSNs in indicated PGC; supplied by the capture program.
- **PGC QRQMT:** Average projected quarterly requirement for entire PGC from first year of program, computed by the capture program from the Program Requirements Trailer.
- **PGC QD:** Historic average quarterly demand for PGC, computed by the capture program from the Demand>Returns Trailer.
- **%A/R:** Ratio of actual to projected demand (ratio of PGC QD to PGC QRQMT) expressed as percentage; computed by the capture program.

The simulation processes one PGC at a time. When a collection of PGCs is to be processed for system-level analysis, the simulation processes each PGC separately and accumulates results. The capture program can be used to prepare a single input file that the simulation can use for different PGCs. To prepare that file, the user must group SSCF reports (which are prepared by NSN) together by PGC for processing by the capture program. When requesting the downloading of SSCF reports, a user should always request NSNs grouped by PGC. (Part of whatever standard procedure DLA develops to move SSCF data to a PC should include the capability to request SSCF data by PGC so that SSCF reports by NSN are automatically grouped together by PGC in the downloaded file.) From a set of SSCF reports grouped by PGC, the capture program builds the required SSCF input file by PGC. Then, when a collection of PGCs is processed sequentially, the simulation will search the SSCF file created by the capture program for each PGC to find its associated NSNs.

#### **MANAGEMENT POLICY TABLE 11 DATA**

A Management Policy Table 11 (MPT011) – also referred to as the Procurement Group Table – exists for every PGC managed by the C&T Directorate (POI and QFD items). The table begins with a header section containing quantitative management parameters for the PGC as a group of similar items, followed by a listing of the individual items (NSNs) in the PGC. The C&T simulation requires only header data from MPT011; all required NSN-level information for the PGC comes from SSCF reports as described earlier. Exhibit A-3

in Appendix A contains an example of an MPT011. The data elements are referenced in DLAM 4140.2, Appendix F-116.<sup>1</sup>

To prepare the required MPT011 input data file for a run, a user must arrange for MPT011s for the PGC (or PGCs) in question to be downloaded from a SAMMS mainframe to the PC, just as is the case for SSCF reports. All the MPT011s should be stored in the file "C:\SIMDLA\MPT011.DAT." Once they have been downloaded to the PC hard drive, a routine built into the C&T simulation extracts the data that are needed for the simulation to run.

Moving from left to right and top to bottom in an MPT011 input file (see Exhibit A-3 in Appendix A), MPT011 data elements used by the C&T simulation are as follows:

- **PROCUREMENT GROUP CODE:** PGC.
- **MINIMUM PROC CYCLE:** The smallest procurement cycle (order quantity expressed in months of demand) among the (possibly) different procurement cycles for the different NSNs in the PGC.
- **DEL %:** Delivery percentages for the PGC – up to 12 entries – reflecting the number of months over which a supplier is to deliver (the delivery period) and the percentage of the total order to be delivered in each of those months.
- **METHOD OF DELIVERY:** 1, 2, 3, or 4 – reflecting one of four possible delivery schemes describing how different NSNs within the PGC are to be delivered over the delivery period [see DLAM 4140.2, Chapter 26, *Delivery Schedules* – (Working Copy)].
- **PGC FIRST DELIVERY DAYS:** Number of days to first delivery for the PGC. (The first delivery for a PGC is assumed to occur at the end of the first month in the delivery period.)

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<sup>1</sup>As of September 1988, the format and content of the header information in MPT011 for C&T PGCs has been revised to allow inclusion of parameters reflecting the new matrix delivery scheduling policy for the C&T Directorate. The C&T simulation requires MPT011s that incorporate the new format and content. DLA documentation of the new MPT011 format and content appears in a revised version of Appendix F-116 of DLAM 4140.2. DLA documentation of new C&T delivery scheduling policies appears in a new chapter of DLAM 4140.2, Chapter 26, *Delivery Schedules*, Volume II, Part 1. Working copy versions of both documents are available from the Defense Systems Automation Center (DSAC), Columbus, Ohio.

- **XYZ ITEM PERCENT:** Cutoff values for NSN order quantity as percentage of total PGC order quantity, used to classify items as X, Y, or Z items in delivery method.

*Note:* Two percentage values are listed to define the X, Y, and Z items. X items are items whose order quantity is greater than or equal to the first value. Z items are those whose order quantity is less than or equal to the second value. All remaining items are Y items.

In addition to the PGC-level header information described above, the MPT011 lists all the NSNs in the PGC. The simulation reads that list but does not use the information in any of its processing. The simulation associates NSNs with a PGC based on the PGC data element that appears in the SSCF data for each NSN. One way for DLA to automate the preparation of raw SSCF data for the simulation would be to arrange for the generation of SSCF reports for NSNs in an MPT011. This would automatically produce SSCF reports grouped by PGC.

The role of MPT011 information in simulating C&T management of PGCs is discussed in the next chapter.

## **SPACE REQUIREMENTS**

The space requirements of the C&T simulation system on the hard disk of a PC are for programs and data. The programs in the system require a total of approximately 4 megabytes of hard disk space: the SIMSCRIPT software requires 2 megabytes (including the swap file of the virtual memory), the simulation program requires 1.3 megabytes, the capture program requires 0.4 megabytes, and the VSL model requires 0.3 megabytes. Space requirements for data are driven primarily by SSCF data. Before capture, the raw SAMMS SSCF file for one NSN requires a maximum of 50 kilobytes (50,000 bytes) of space. Pure QFD NSNs require about 15,000 bytes per NSN. After capture, a maximum of 1 kilobyte per NSN is required, and the raw SSCF file can be deleted from the PC hard disk.

## CHAPTER 3

### HOW THE C&T SIMULATION WORKS

#### OVERVIEW

Wholesale inventory management has four aspects: forecasting requirements, controlling inventory, responding to customer demand, and dealing with suppliers. Everything that happens in an inventory management enterprise can be understood in terms of these four activities and the way they interact. A way to understand how the C&T simulation works is to see how it handles these activities.

In its treatment of the four aspects of inventory management, the simulation captures the key features of C&T operations that must be considered when new policies are being reviewed. However, because it is a model — that is, a simplified idealization of a complex activity in the real world — the simulation does not capture everything that goes on in C&T operations. It is sometimes tempting to forget that fact and treat the simulation as though it were a miniaturized version of the entire C&T enterprise, suppliers and customers included, sitting inside a large box, busily replicating everything that goes on in the world. It is important to resist such a temptation. The simulation is a computer model that does what it does by manipulating information and data in a sequence of operations within a computer. It cannot go beyond what its data, algorithms, distributions, and assumptions allow it to do.

As an example, no data are yet available to show how C&T suppliers will react to the new matrix delivery schedules being introduced. In the real world, suppliers will react and leadtime variabilities will change in some way. If we had a miniature version of the real C&T world in a box, we could lift the lid and see whether the new matrix schedules result in suppliers delivering more orders on time. With the simulation, the best we can do is adjust the distribution that controls when deliveries occur and then measure the effects if delivery performance improves.

Although the simulation cannot address all possible questions, it can address a large number of them. This makes it important, when deciding whether the model can be applied to a given problem, to have a clear view of what is in the model and



what is not. This chapter provides that information. It describes how requirements forecasts are generated, how inventory is controlled, how customer demand is modeled, and how supplier responsiveness is simulated. Potential users can see where special attention has been paid, how input data are used, and where technical emphasis has been placed.

The C&T model is a discrete event simulation model; that is, it employs variables whose values change a finite number of times over the course of a run, based on the rules, procedures, calculations, and probability distributions built into the model.<sup>1</sup>

The basic unit of simulation is the PGC, whether multi-item or single item. Each time the simulation runs, it simulates what happens over time to a single PGC in the C&T inventory management process. In general, the following things "happen" to a PGC: requirements forecasts are made; stock levels, reorder points, and order quantities for each NSN in the PGC are set and periodically recomputed; stock is drawn down by customer demand; reorder points are reviewed; replenishment orders are placed with suppliers; and stock is replenished when replenishment orders are delivered. In the simulation, all of those processes are modeled by assigning values to variables and then allowing those values to change according to the schedules, rules, and probability distributions that constitute the model.

## FORECASTING REQUIREMENTS

Requirements forecasts are projections of future demand. In the real-world C&T system, requirements are forecasted and updated for each NSN in SAMMS on a monthly or quarterly basis and stored in Supply Control Files. The simulation, however, does not have new requirements forecasts being presented to it from external sources over time. It must generate its own "new" requirements forecasts based on one single instance of a requirements forecast as recorded in the Program Requirements Trailer of an SSCF report. As simulated time proceeds, the

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<sup>1</sup>Discrete event simulation contrasts with continuous simulation. In a continuous simulation, differential equations are used to describe how variables change over time, and integrations are performed to solve for particular values after intervals of time have "elapsed." A continuous simulation of C&T operations was developed by DPSC/Operations Research and Economic Analysis Office in conjunction with work on the new C&T matrix delivery schedules.

simulation must generate a new requirements forecast for each NSN in the PGC it is processing. It does this for POI items as follows.

At the beginning of a run, input data from the Program Requirements Trailer for a POI item provide the simulation with a statement of projected program requirements for the NSN for up to 36 months into the future. The simulation computes the average value and standard deviation of those 36 monthly data points and constructs a normal distribution with that mean and standard deviation. It then draws 60 times from that normal distribution to build a  $(1 \times 60)$  array representing projected monthly demand requirements for the next 5 years of simulated time. As simulated time proceeds, new draws are made and the requirements array is updated periodically so that the simulation always has access to a projected monthly requirements forecast extending 5 years into the future. If the POI item has a nonzero QFD value in its input data – indicating the item has demand sources not incorporated in the POI program – the QFD value is divided by three and each monthly POI forecast is increased by the  $QFD/3$  amount whenever the requirements array is used. The forecast sum is referred to as  $F_i$  in this chapter.

Part of what makes POI items unique in SAMMS is that forecasted requirements are based on future program forecasts rather than historical demand. Quantitative levels (i.e., reorder points, order quantities, and acquisition objectives) are set in terms of "months of demand." For POI items, therefore, the simulation needs the "rolling" 5-year requirements forecasting array described above to be able to compute and periodically update quantitative levels in the same way they are updated in SAMMS. A requirements array extending 5 years into the future is long enough to accommodate the range of leadtimes and procurement cycles that occurs in the C&T program.

The procedure described for simulating the forecasting of POI requirements yields forecasts that are like the input forecast in terms of mean and standard deviation. The simulated forecasts will not reflect a pattern of steadily increasing or decreasing demand, however, if such a trend is present. This complicates the problem of using the simulation to analyze the effects of trends. In the real world, if a demand trend holds up over several forecasts, the C&T system will adapt with steadily increasing or decreasing inventory control levels. To produce the same effect in the simulation, it would be necessary to modify the simulation to either do

multiple runs on a single 36-month forecast or build in a trend-inducing factor to cause requirements to rise over time in the rolling requirements array.

The preceding discussion applies to a POI item. For a pure QFD item, there is no draw from a normal distribution to obtain the monthly forecast. The forecast for every future month is simply the quarterly forecasted demand value from the SSCF report divided by three. Just as the procedure for POI items was designed to be consistent with SAMMS processing, this procedure for QFD items is consistent with the way pure QFD items are treated in SAMMS. In SAMMS, when quantitative levels are computed for pure QFD items, the QFD value in the Supply Control File is treated as the underlying, stationary demand rate for the item for all future time. (This assumption is standard in inventory control systems in which quantitative levels are periodically updated and, in fact, is the reasonable thing to do. Even though a new set of quantitative levels will be computed a month or a quarter later using new data, the QFD value at the time of any given computation represents the current best estimate of what the demand rate will be in the future.)

The next section describes how requirements forecasts are used in setting quantitative levels. In the section after next, we will see how requirements forecasts also affect how customer demands are generated.

## **CONTROLLING INVENTORY**

In this section, we define how quantitative levels – reorder points, order quantities, and acquisition objectives – are set and used in the C&T simulation. Throughout, the procedures described are identical to the procedures used in SAMMS for controlling C&T inventory.

An inventory system is a system in which stocks are held, issued, and replenished. The behavior of inventory in such a system is controlled by the rules governing when replenishment orders will be placed and how much they will be for. The C&T system and the simulation both employ a reorder point, order quantity, order-up-to-an-acquisition-objective methodology to decide when orders will be placed and how much they will be for.

### **Reorder Point**

In the C&T simulation, each NSN within a PGC is assigned a reorder point – either on a monthly or quarterly basis depending on whether the item is a

VIP item or not. For NSNs with POI requirements, the reorder point (ROP) is the number defined as follows:

$$ROP = \sum_{i=1}^{ROP \text{ Period}} F_i + \left( \sum_{i=1}^{12} \frac{F_i}{12} \right) \times SL + OWRMRP, \quad [\text{Eq. 3-1}]$$

where  $F_i$  denotes the forecasted program requirement in month (i) from the "rolling" 60-month requirements array described in the previous section, the ROP period is the procurement leadtime in months, SL denotes the safety level in months for the item, and OWRMRP is the Other War Reserve Materiel Requirements Protectable. (OWRMP is a DoD term used to denote a category of wholesale-level war reserve stocks. The C&T Directorate policy is to include OWRMRP in C&T reorder points.)

For pure QFD items, the reorder point is defined as follows:

$$ROP = \left( \frac{QFD}{3} \right) \times ROP \text{ Period} + \left( \frac{QFD}{3} \right) \times SL + OWRMRP \quad [\text{Eq. 3-2}]$$

Normally, the meaning of a procurement leadtime is well-defined in the discussion of a reorder point. A procurement leadtime represents the sum of administrative leadtime and production leadtime (ALT+PLT), and both ALT and PLT are input data elements from an SSCF report. The new matrix delivery policies being introduced at the C&T Directorate, however, affect how PLTs will be defined for purposes of setting reorder points. Because the matrix delivery policies are new, Supply Control Files do not yet reflect the new PLTs. To make the simulation compatible with the new delivery policies, we have incorporated a different procedure for determining what the PLT is for an item (NSN). Rather than simply reading the PLT from the SSCF input data, the simulation computes a PLT from data in the MPT011 for the PGC containing the NSN since the information defining new C&T delivery schedules has been incorporated into the MPT011s.

For purposes of setting reorder points, PLTs are derived from MPT011 input data as follows: The order quantity for the NSN (defined later in this section) is compared with the sum of the order quantities for all NSNs in the PGC. Depending on the NSN's order quantity percentage relative to the total PGC order quantity, the NSN is classified as an X, Y, or Z item according to the XYZ item percent cutoff values in the MPT011 input data. The delivery method for the PGC containing the NSN is also obtained from the MPT011 input, as is the number of days to first delivery for the PGC. The simulation counts the number of consecutive nonzero

delivery percentages in the MPT011 data to determine the number of months over which deliveries are to be made. That number of months is referred to as the delivery period and represents the number of delivery increments. With that information, the simulation computes a PLT in days for the NSN as the following sum:

$$\text{PLT} = \# \text{ of days to first delivery} + (\# \text{ of delivery increments} \times 30) \times \text{DPF}, \quad [\text{Eq. 3-3}]$$

where DPF denotes a delivery period factor whose value depends on whether the item is an X, Y, or Z item and what the method of delivery is. The particular values for DPF that are programmed in the model are those described in Chapter 26 of DLAM 4140.2, *Delivery Schedules* (Working Copy), available from DSAC. As an example, for an X item under Method of Delivery 1, the DPF is one-third. With a 6-month delivery period, this makes the second term in Equation 3-2 equal to 60 days (2 months). The idea of the DPF is to set the PLT so that it falls at a reasonable point within the delivery period for an item whose order quantity is delivered in increments over several months.

The most important aspect of this way of defining the reorder point PLT is that both in the real world and in the simulation, PLTs will be based on a planned schedule rather than on actual leadtimes achieved by suppliers. This policy reflects a deliberate DLA decision to exercise greater control over C&T leadtimes and their effect on C&T stockage levels. The new delivery schedules are supposed to better reflect what manufacturers and suppliers can actually deliver. If this holds true, policy-based PLTs and actual PLTs will not be all that different. As discussed earlier, however, the simulation cannot be used to see whether suppliers will indeed do a better job of meeting the new schedules. Data on that subject are not available, and the simulation cannot be "bootstrapped" into answering the question without such data.

Eventually, historical PLT values in C&T Supply Control Files will be replaced or augmented by schedule-based PLTs. (It is important to record and save historical PLTs somewhere in SAMMS in order to monitor supplier response to the new schedules and to provide the data needed for leadtime variability analyses.) When the new PLTs are incorporated into Supply Control Files, it will be possible, with some reprogramming, to revert to the use of SSCF PLT values in the simulation if DLA so desires. MPT011 information can be used, however, as long as PLTs for reorder points are based on planned delivery schedules. Used in this way, MPT011s

have the added advantage of providing additional flexibility for applications. In particular, before running the model, users can change MPT011 input data through the use of an alternative MPT011 input file, making it possible to experiment with different delivery methods for multi-item PGCs.

A final point on the new delivery schedules: separate from their role in the setting of PLTs for reorder points, they will also influence how deliveries actually occur – both in the real world and in the simulation. In particular, both in the real world and the simulation, the time to delivery for a given item after it has been ordered will generally be different from the leadtime used to set its reorder point. Some of this difference between reorder-point leadtimes and actual leadtimes is inevitable, of course, given the ever-present variability in leadtimes. However, the normal differences may be exacerbated by the way in which new delivery schedule logic is being implemented in SAMMS. In the next section, we describe the way delivery schedules are used to generate supplier deliveries. We include a discussion of the role and effects of the "needs test," and how it has been incorporated into the model. In Chapter 7, we present and discuss some of the potential problems that may arise from delivery schedule implementation. At this stage, having described how PLTs are determined for purposes of setting C&T reorder points, we return to the general discussion of reorder points and quantitative levels.

In logical terms, the reorder point is equal to the average demand in a leadtime plus safety level and the protectable war reserve requirement. The basic role of a reorder point is to serve as a trigger alerting the item manager to the possible need for a replenishment order. In the real C&T system, under SAMMS processing, the inventory position for an item (on hand plus on order) is compared three times a week with the reorder point increased by any outstanding unit backorders.<sup>2</sup> In the C&T simulation, the comparison is made every other day of simulated time.

With a simple change to the model, the user can change the frequency of the reorder point comparison. Increasing the time between reorder point checks is one of three ways that users can make the simulation run faster. The other two are to change the frequency of demand generation and to switch off the logic for generating

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<sup>2</sup>Comparing the inventory position (on hand plus on order) to the reorder point increased by outstanding backorders is equivalent to comparing the asset position (on hand plus on order minus outstanding backorders) to the reorder point. The asset-position comparison is used in the C&T simulation.

and tracking requisition demand. The latter two options are discussed in the next section on generating customer demand. All three ways speed up processing time at the expense of certain aspects of system realism.

The basic idea of a reorder point is that, at the time of a breach, enough stock is on hand and on order to cover demand through a leadtime with a reasonable expectation of avoiding backorders, but an order should be placed now so that replenishment stocks will arrive when needed a leadtime later. For a multi-item PGC, each NSN has its own reorder point but the placement of replenishment orders is more complicated, as will be described in a moment.

The safety-level-in-months term in the reorder point expression may be the value of fixed safety level for the item, read from the input data, or it may be a value obtained from a file of VSLs computed with the C&T VSL model described in detail in Appendix D). Here, it suffices to say that the C&T VSL model operates on exactly the same input data as the simulation and prepares a file of VSL values for the set of NSNs, grouped by PGC, that a user wishes to study. (The VSL model can compute VSL values to either a safety level investment target or a supply performance target, for whatever collection of NSNs it is given. That collection may be the NSNs within a single PGC or those contained in several PGCs.)

For multi-item PGCs, the C&T Directorate employs a unique reordering procedure that goes beyond the simple comparison of an NSN's reorder point with its asset position. Before describing that procedure, however, we have to define the second quantitative level used in controlling inventory – the order quantity – and the associated notion of a procurement cycle.

### **Order Quantities**

The order quantity (sometimes called the procurement quantity) for an NSN represents the maximum number of units of the item that will be ordered on a single replenishment order to a supplier. The associated procurement cycle is the number of months of demand (using the average monthly demand rate over the next 12-month period) that the procurement quantity represents. Procurement cycles are of interest because they give an indication of how frequently the procurement system

will have to procure the item. Procurement quantities (PC.EOQ) and associated procurement cycle periods (PCPs) for C&T POIs are computed in two steps as follows:

- *Step 1.* Determine the dollar value of quarterly demand (DVQD):

$$DVQD = \frac{\sum_{i=1}^{12} F_i \times \text{Cost}}{4} \quad [\text{Eq. 3-4}]$$

- *Step 2.* Set procurement quantities and cycles as follows:

$$DVQD \leq M_1 = \$925 \quad PC.EOQ = \sum_{i=1}^{36} F_i \quad (\text{units}) \quad [\text{Eq. 3-5}]$$

$$PCP = 36 \quad (\text{months})$$

$$M_1 < DVQD \leq M_2 \quad PC.EOQ = \frac{T \times \sqrt{DVQD}}{\text{Cost}} \quad (\text{units})$$

$$(T = 365)$$

$$PCP = \frac{PC.EOQ}{\sum_{i=1}^{12} F_i / 12} \quad (\text{months})$$

$$DVQD > M_2 = \$9,999 \quad PC.EOQ = \sum_{i=1}^6 F_i \quad (\text{units})$$

$$PCP = 6 \quad (\text{months}),$$

where  $F_i$  denotes the forecasted program requirement in month (i) from the "rolling" 60-month requirements array. For pure QFD items, the order quantity/procurement cycle rules are similar, with the  $F_i$  values replaced by QFD/3 throughout.

The values shown for  $M_1$ ,  $M_2$ , and  $T$  are the default values in the simulation. They can be changed prior to a run through the use of the Alternative Assumption File. (See the description of Query 11 in Chapter 6 for instructions on using the Alternative Assumption File and Exhibit A-4 in Appendix A for an example of what the Alternative Assumption File looks like.) The cutoff values in Equations 3-4 and 3-5 are new values assigned to C&T in the spring of 1988, replacing values of  $M_1 = 51.36$ ,  $M_2 = 1,528$ , and  $T = 86$  used prior to that time. The  $T$  factor is defined by



$$T = 2 \sqrt{\frac{2P}{I}} \quad [\text{Eq. 3-6}]$$

where P denotes the cost of placing an order and I denotes the holding cost rate (holding cost as a percentage of unit cost). DLA uses the T factor to simplify order quantity calculations when all items at a given supply center are assigned the same ordering cost and holding cost rate.<sup>3</sup>

The middle value of the procurement quantity in Equation 3-5, when DVQD lies between the M<sub>1</sub> and M<sub>2</sub> values, is the traditional Wilson lot size economic order quantity (EOQ) of inventory theory. Assuming a value of 18 percent (I=0.18) for the holding cost rate in the expression for T, a value of 365 for T implies an order cost, P of \$2,998 per replenishment order at C&T. The M<sub>1</sub> cutoff value of \$925 is consistent with the DVQD value at which the Wilson lot size corresponds to 36 months of demand. That is, for DVQD values smaller than \$925 and a T factor of 365, Wilson lot sizes are more than 36 months of demand. The M<sub>2</sub> value of \$9,999, however, does not correspond to the DVQD at which Wilson lot sizes become less than 6 months of demand. In the lot size formula, with a T value of 365, DVQD has to be greater than \$33,306 to yield a procurement cycle of less than 6 months, and the value of \$9,999 yields a Wilson lot size procurement cycle of 11 months. Nevertheless, following C&T policy and SAMMS implementation, the M<sub>2</sub> value of \$9,999 is used as the cutoff for establishing procurement cycles of 6 months.

With these definitions of reorder point and order quantity/procurement cycle, we can now describe the reordering process for multi-item PGCs. Each multi-item PGC has a minimum procurement cycle defined in its MPT011, normally (but not necessarily) representing the smallest procurement cycle among the NSNs in the PGC. The reordering rule for the PGC is that whenever one NSN has breached its reorder point, it and any other NSN that is within a minimum procurement cycle of breaching its reorder point are subject to being ordered.

In the real world, a C&T item manager may, for one reason or another, elect not to place an order even though reorder conditions have been met. Procurement funds may be constrained, for example. Or, rather than placing an order, the item

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<sup>3</sup>For a discussion of EOQ computations and other demand-based levels in SAMMS, see M. K. Cyrus, et al., *Review of SAMMS Requirements Computations*, Chapter III, DLA Operations Research and Economics Analysis Office, Headquarters, Defense Logistics Agency, Cameron Station, Alexandria, Virginia, Aug 1985.

manager may be able to modify an existing order to satisfy the new requirement. (In the past, suppliers have allowed C&T item managers to change the mix of sizes in an order for a multi-item PGC provided the order was still at least 90 days from its scheduled delivery. The need for order changing is supposed to decrease under the new matrix delivery policies.)

In the C&T simulation, when one NSN breaches its reorder point, it and all other NSNs in the PGC that are within a minimum procurement cycle of breaching their reorder points are ordered. NSNs that are not within a minimum procurement cycle of breaching are not ordered. The model does not simulate order changing, nor does it allow a funding constraint to prevent an order from being placed. (Both of those capabilities would require additional programming of the model.) The test to see whether an item is within a minimum procurement cycle of breaching its reorder point is done, for a POI item, by examining the forecasted requirements array; for a pure QFD item, it is done by calculating demands at a rate of QFD/3 per month.

### Acquisition Objective

The final quantitative level to define is the Peacetime Acquisition Objective (PTAO). The PTAO determines the actual size of an order when it is placed. It is simply the sum of the reorder point and the order quantity:

$$PTAO = ROP + PC.EOQ \quad [Eq. 3-7]$$

The PTAO represents the upper bound on the number of units of an item that should be on hand or on order at any given time. Like its constituent parts (the reorder point and the order quantity), the PTAO is updated monthly for VIP items and quarterly for non-VIP items.

The C&T rule for replenishment orders is now as follows: if at a given time,  $t$ , an NSN has breached its reorder point (set earlier at the beginning of either the month or the quarter), then for that NSN and all other NSNs in the PGC within a minimum procurement cycle of breaching, compare the asset position (on hand plus on order minus outstanding backorders) as it exists at time,  $t$ , to the PTAO as it exists at time,  $t$ . If the asset position is less than the PTAO, order a reorder quantity equal to the difference. In other words, when placing an order, order up to the acquisition objective for each NSN in the PGC that qualifies for reorder.

Reorder point values and other quantitative-level values are not updated at the time of a reorder; they will not change until the next regularly scheduled update at the beginning of the next month or quarter. Actual quantities ordered, however, are computed on the basis of level requirements as they exist at the time of the order. The rationale is that if an order is actually placed, it should conform to the most up-to-date computation of what the levels in the system should be.

This completes the discussion of quantitative levels. We next describe how customer demand is simulated.

## **MODELING CUSTOMER DEMAND**

In addition to mimicking the internal controls (i.e., quantitative levels) the C&T Directorate uses to control inventory, the C&T model must also simulate customer behavior. In the real world, customers interact with C&T in many different ways. In the simulation, we focus on the two key interactions that most strongly affect C&T performance: demand forecasting and demand itself. In the forecasting interaction, customers present the C&T Directorate with forecasts of their future troop strengths and inductions. That interaction is modeled in the requirements forecasting part of the simulation. In the demand interaction, customers actually place demands, and that also must be simulated.

C&T's customers are retail-level supply outlets at military installations and bases. Their demand on the wholesale C&T system comes in the form of requisitions; that is, retail outlets requisition materiel from C&T stock in varying lot sizes to replenish their own retail-level stocks, which they in turn issue or sell to their customers, who are the final consumers of C&T items. In honoring requisitions, C&T item managers draw down units of on-hand stock at the wholesale level. As stock is drawn down, C&T item managers (using SAMMS) track changes in the unit asset position and compare that position periodically to the reorder point quantity to decide when and how much to order. Simulating customer demand and how it interacts with the inventory control system, therefore, means generating and keeping track of *both* unit demand and requisition demand.

Unit demand in the C&T simulation is calculated and generated using a two-step process. First, a draw is made from a probability distribution for the total number of unit demands that will occur in a given month. Once that total has been drawn, demands are then actually generated on a daily basis over the course of the

month.<sup>4</sup> The same process is repeated for the next month and each month thereafter for the duration of the simulation. The entire procedure is done by NSN, simultaneously for each NSN in the PGC, using NSN-specific data to define the distributions.

The distributions from which the monthly unit demand totals are drawn are obtained as follows: Each NSN has a projected monthly demand value for a given month. For a POI item, the value is the relevant entry in the 60-month requirements array plus QFD/3. For a pure QFD item, it is the QFD value from the SSCF report divided by three. This monthly value is taken as the mean for a normal distribution, with a standard deviation derived from the item mean absolute deviation (MAD) taken from the SSCF input data. MAD is a measure of forecast error defined in SAMMS as follows:

*Step 1.* Determine the forecast error in month  $m$  as follows:

$$\text{Forecast Error (in month } m) = \left[ \frac{\text{QFD}(m)}{3} + \text{POI Forecast } (m) \right] - \text{Actual Demand } (m). \quad [\text{Eq. 3-8}]$$

*Step 2.* Define MAD for month  $(m + 1)$  by:

$$\text{MAD } (m + 1) = \alpha [\text{Forecast Error } (m)] + (1 - \alpha) \text{MAD } (m), \quad [\text{Eq. 3-9}]$$

where  $\alpha$  is the alpha factor from the SSCF data (defined in DLAM 4140.2, Vol. II, Part 3, Appendix F-262, "Alpha Factor Table 008," with C&T updates).

For a VIP item, MAD is converted to a standard deviation for the normal distribution of monthly demand by multiplying by 1.25, following SAMMS practice.<sup>5</sup> For a non-VIP item, MAD is a measure of the mean absolute deviation in quarterly demand. The MAD for a non-VIP item is converted to a monthly standard deviation by multiplying by 1.25 to obtain a quarterly standard deviation and dividing by the square root of three. The rationale for dividing by the square root of three is that the

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<sup>4</sup>With a simple change to the model, demands can be generated less frequently – e.g., on a weekly rather than daily basis. This change slightly speeds up model run time because fewer demand-generation operations must be performed. However, weekly demand generation also requires longer runs to achieve the same level of precision in results. Daily demand generation was chosen as the default mode for the model because, according to C&T item managers, requisitions for many C&T items arrive every day and daily unit demand generation is necessary to accommodate that level of requisition frequency.

<sup>5</sup>The rationale for converting a MAD to a standard deviation by this method is given in Robert G. Brown, *Smoothing, Forecasting, and Prediction of Discrete Time Series* (Englewood Cliffs, New Jersey: Prentice-Hall, 1963).

variance in quarterly demand is assumed to be three times the variance in monthly demand and standard deviation is the square root of variance. The total number of demands that will occur in a given month in the simulation is the draw from the normal distribution with mean and standard deviation as described.

In summary, *two* normal distributions are involved in the unit demand generation process for POI items. The first is the normal distribution used in simulating the requirements forecasting process. Its mean and standard deviation are computed from the monthly forecasts in the Program Requirements Trailer in the SSCF input data. That normal distribution is drawn from to make the rolling 60-month requirements array. The second normal distribution applies to a single month. Its mean is the value from the 60-month requirements array for the month in question, and its standard deviation is obtained from the item MAD.

As noted earlier, unit demands in the simulation are actually generated daily. The total demands drawn for the month are divided by 30 to determine daily demands. (Every month in the simulation is 30 days long.) Thus, within a month, the unit demands are the same from one day to the next. Users have the option of generating unit demand less frequently than daily, if desired. They may also draw daily demands from a Poisson distribution with mean equal to the monthly demand divided by 30. (This option requires a minor programming change in the model and introduces an extra source of variance that may not be desirable.)

The preceding method yields unit demand patterns that conform to C&T demand experience as reflected in C&T data. For some applications, however, users may wish to experiment with different demand patterns. If the forecasted demand for a PGC is believed to be too high or too low, users may want to take that into account. Users can reduce or increase generated demands through the use of a demand *control knob* at the beginning of a run. The demand control knob changes the value of the means in the normal distributions from which monthly demand values are drawn. For example, a value of 0.95 will convert every forecasted monthly mean to 95 percent of its value prior to demand generation, while a value of 1.05 will increase every mean to 105 percent of its value.

The next step is to describe how *requisition* demand is generated. Requisitions are modeled as accumulated unit demand. To decide when enough unit demands have accumulated to generate a requisition, the simulation performs a computation

involving the average requisition size of the NSN and a distribution for the ratio of requisition size to average requisition size.

Average requisition size by NSN is computed from the input data in the Demand/Returns Trailer of the SSCF report and is stored as a data element in the SSCF input file for the model [see the description of the average requisition size (ARS) data element in Chapter 2].

The distribution for the ratio of requisition size to average requisition size is one that applies to all requisitions arriving at DPSC. It was developed for DLA's Uniform SAMMS Inventory Management Simulation (USIMS) based on 1984 data.<sup>6</sup> The distribution reflects DPSC experience with subsistence and medical items, as well as with C&T items. The distribution applies to DPSC items whose average requisition size is greater than five. The distribution is shown in Appendix A in Exhibit A-5.

To generate a requisition, a draw is made from the USIMS distribution to obtain a ratio, which is then multiplied by the average requisition size for the NSN. This gives a requisition size number for the next requisition. As soon as enough unit demands have accumulated to equal (or exceed) the requisition size number, the requisition demand occurs, the requisitioned number of units of stock are drawn down, a new draw is made, and the next requisition size number is generated. Remaining unit demands, if any, begin to accumulate towards the next requisition. If insufficient stock is on hand to fill the requisition, whatever units are on hand are drawn down, unit backorders are generated for the difference, and the requisition is counted as a "nonfill" in determining requisition supply availability.

For the half dozen PGCs examined during development (chosen by the DLA C&T Directorate as a small, representative cross-section of its items), the simulation's demand-generating process results in requisitions occurring roughly every 1 to 4 days.

To sharpen the process for generating requisitions, DLA should obtain the USIMS requisition-size distribution for C&T items alone. The distribution now used is clouded by the inclusion of medical and subsistence items. An alternative

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<sup>6</sup>Appendix W of the Uniform SAMMS Inventory Management Simulation (USIMS) User's Guide, January 1986, available from the DLA Operations Research and Economic Analysis Office, documents the requisition size distributions developed for USIMS.

approach is to construct NSN-specific distributions. From the four quarters of historical demand data in Trailer E of an SSCF report where both quantity demanded (unit demand) and frequency of demand (number of requisitions) are recorded, DLA could construct NSN-specific distributions of requisition size for each NSN in a PGC rather than using the DPSC-wide distribution. We have not included this feature in the current version of the simulation but we could add it in the future.

A special feature of the C&T simulation is its ability to separately identify and track demand from Recruit Training Centers (RTCs). It does so in the requisition generation process.

Thus far, we have seen that both unit demands and requisition demands are generated in the simulation from what amounts to a single source. The simulation does not have multiple demand generators representing the multiple retail supply activities that place demands on the C&T system in the real world. Nevertheless, the simulation identifies RTC demand. It does so by recognizing that RTC demand tends to come in the form of large requisitions; that is, replenishment requisitions from RTCs are usually for sizable quantities. The key to identifying RTC demand, therefore, involves deciding what constitutes a large requisition.

As described in Chapter 2, the SSCF input data file contains a percent RTC demand figure computed from the Program Requirements Trailer (Trailer U) data for each NSN. That percent represents the portion of total projected unit demand associated with "Initial Issue - Recruit" program identification codes. The percent RTC demand figure, in conjunction with the underlying probability density function (pdf) for requisition size for the NSN, can be used to find the right requisition-size cutoff value for RTC requisitions using the following argument:

Find the cutoff value,  $c$ , such that:

$$\sum_{i \geq c} f_i(i) = \text{RTCP} \sum f_i(i), \quad [\text{Eq. 3-10}]$$

where  $f_i$  denotes the absolute frequency of requisitions of size  $i$  and RTCP denotes the percentage of RTC demand. The product of frequency and requisition sizes, summed over all requisition sizes, yields total unit demand, and the sense of Equation 3-10 is that requisitions whose size is greater than or equal to  $c$  account for the RTC

percentage of total unit demand. Converting the absolute frequencies,  $f_i$ , to relative frequencies,  $r_i$ , by dividing by  $\sum f_i$  yields the equivalent problem:

Find  $c$  such that

$$\sum_{i \geq c} r_i(i) = \text{RTCP} \times \text{ARS}, \quad [\text{Eq. 3-11}]$$

where ARS denotes the average requisition size. The relative frequencies,  $r_i$ , are the probabilities that make up the pdf for requisition size underlying the USIMS distribution.

Figure 3-1 illustrates how the cutoff value is determined for an item with an average requisition size of 25 units and a percent RTC demand value of 30 percent. The lower curve in the figure is a graph of

$$\frac{\sum_{i=1}^c r_i(i)}{\text{ARS}}, \quad [\text{Eq. 3-12}]$$

(expressed as a percentage) plotted over requisition size,  $c$ . The upper curve is a plot of the cumulative distribution function (cdf) for requisition size. The percentage of demand associated with requisitions of size,  $s$ , or less is obtained by locating  $s$  on the horizontal axis and reading up and across to the left. In the figure, 70 percent of demand corresponds to requisitions of 113 units or less, so 30 percent of demand comes from requisitions of more than 113 units, and 113 units is the desired cutoff value for determining RTC requisitions for this item.

The generation and tracking of requisition demand, including the separate identification of RTC requisitions, is an important feature of the C&T simulation. However, it is possible to run a unit-demand-only version of the simulation using a switch in the Alternative Assumption File that shuts off the requisition-generating machinery. The model runs about 30 percent faster if requisitions are not generated. Running the model in this mode is appropriate when overall unit demand and supply performance are the only measures of interest.

## **SIMULATING SUPPLIER RESPONSIVENESS**

Supplier responsiveness – the ability of suppliers to deliver replenishment orders on time – is the final C&T operation to be simulated. Supplier



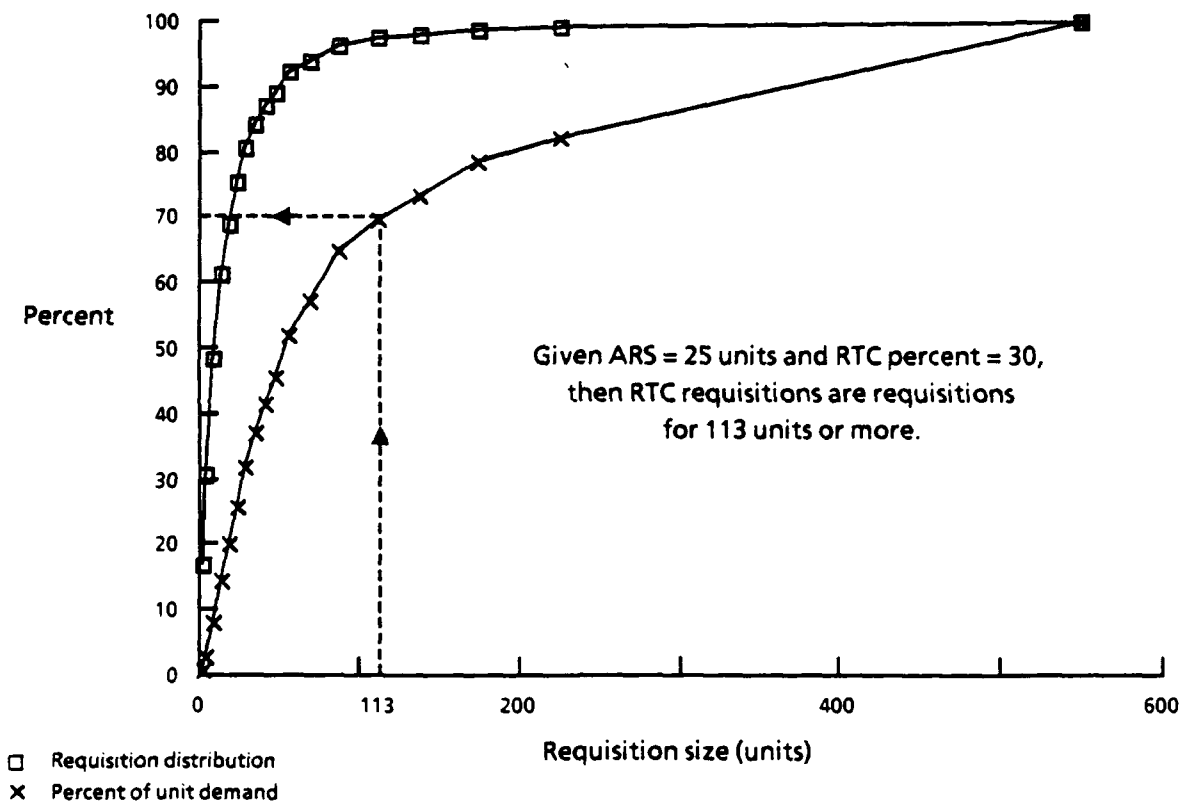


FIG. 3-1. RTC REQUISITION SIZE CUTOFF LOGIC

responsiveness, or the lack of it, affects C&T's inventory performance at least as much as changing customer demands and internal inventory controls. C&T suppliers, many of whom are small businesses, are subject to market forces that can strongly influence their ability to produce and deliver on time. C&T is also just one among many customers competing for clothing and apparel items in the economy.

The simulation of supplier responsiveness is based on administrative leadtimes in Supply Control Files, delivery schedule plans in Management Policy Tables, and historical information on contractor delinquencies. The simulation combines all this information to determine when replenishment orders are delivered. In the simulation, emphasis is placed on inventory effects rather than contract management: no attempt is made to simulate the contractual activities involved in the placing of orders. Following the reordering processes described earlier, replenishment orders are simply placed and stock arrives late or early. Leadtime variability (i.e., whether deliveries are late or early) is based on draws from a

probability distribution that describes how suppliers perform in the real world. The user can change degree of leadtime variability through a control knob.

The first step in determining when and how a replenishment order will be delivered is to determine the matrix delivery schedule for each item. The methodology for constructing those schedules is given in DLAM 4140.2, Chapter 26, *Delivery Schedules* (Working Copy). In some schedules, the entire order of an NSN is delivered at one time in a "clump." In other schedules, the order is delivered incrementally over several months. The type of delivery schedule depends upon the information in the MPT011: the method of delivery, the XYZ cutoffs that determine whether a NSN is an X, Y, or Z item, and the delivery percentages by month for the order.

The individual delivery schedules for the X, Y, and Z items are calculated at the beginning of the simulation and do not change. Each item schedule specifies what percent of the item's total order is delivered in each month of the delivery period for the PGC. The schedules depend on the matrix delivery method and are constructed so that the sum of all deliveries in any month equals the delivery percentage for that month. Each of the four matrix delivery methods is different.

In Method 1, the NSNs with the largest orders are delivered first. Deliveries are spread across the delivery period until all NSNs are delivered. The distinguishing feature of Method 1 is that the entire order for each NSN is delivered at one time in a clump.

In Method 2, all Z items are delivered in clumps in the last month of the delivery period; Y items are delivered incrementally in the last half of the period; and X items are delivered incrementally across the entire period.

In Method 3, Z items are delivered in clumps across the last two-thirds of the delivery period, while X and Y items are delivered incrementally across all delivery months.

Method 4 is identical with Method 3 except that Z items are delivered only in the last month of the delivery period.

The next step is to determine the delay for the delivery. To do so, the simulation employs an empirical distribution. The histogram for the delivery delay distribution is shown in Figure 3-2. The distribution was constructed from data in

C&T Contract Line Item Number (CLIN) Delinquency Reports for the months of April, June, August, September, and October 1987. The CLIN Delinquency Reports record both the number of outstanding contract line items for which suppliers have missed delivery dates and the percentage that number is of the total number of active CLINs. Table 3-1 contains the relevant CLIN data underlying the histogram in Figure 3-2.

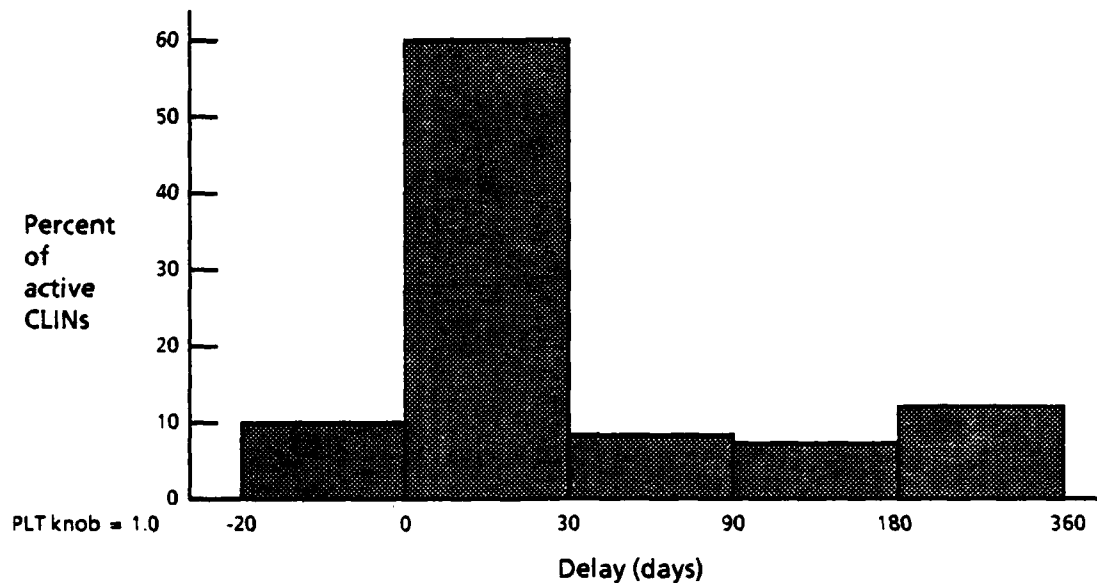


FIG. 3-2. DELIVERY DELAY HISTOGRAM

TABLE 3-1

1987 C&T CLIN DELINQUENCY REPORT DATA

1987 month	Total CLINs	31 - 90 days late		91 - 180 days late		> 180 days late	
		Number	Percent	Number	Percent	Number	Percent
April	26,757	1,927	7.20	1,442	5.39	3,133	11.71
June	25,223	1,900	7.53	1,215	4.82	3,091	12.25
August	25,702	2,087	8.12	1,710	6.65	3,157	12.28
September	25,297	2,068	8.17	1,845	7.29	3,388	13.39
October	22,995	1,650	7.18	1,819	7.91	2,876	12.51
Average			7.64		6.41		12.43

The assumption is that items ordered in the simulation correspond to active CLINs (i.e., line items on order). The three right-hand bars in the histogram correspond to the average percentage values of 7.64 percent, 6.41 percent, and 12.43 percent in Table 3-1. The upper bound of 360 days late was based on discussions with C&T personnel, who indicated that very late contracts (contracts later than 12 months) would generally be moved into a different status and new contracts would be let. With this configuration of the delivery delay distribution, the simulation assumes that, even if a second contract is required, delivery is never more than 360 days late. Similarly, the leftmost bar in the histogram is based on subjective C&T estimates that no delivery would ever be more than 20 days early and that no more than 10 percent of contracts would be delivered early in any case. The tall bar in the histogram represents what is left – the contracts that are delivered essentially on time, i.e., within 30 days of scheduled delivery.

Each time a replenishment order is placed in the simulation, the total leadtime is determined and a draw is made from the delay distribution to determine how many days late or early the delivery will be made in relation to the total leadtime.

The simulation determines when deliveries take place by summing three factors: the administrative leadtime in days, the time to first delivery in days, and the delay time in days drawn from the delivery delay distribution. The sum is the number of days that pass from the time an order is placed to the time of the first delivery at the end of the first delivery month in the schedule. The second delivery occurs 30 days later at the end of the second delivery month and so forth until the delivery schedule is completed.

Because of the way matrix delivery schedules are designed for some items, the actual delivery leadtime will not equal the reorder point leadtime even if no delivery delay occurs. With incremental deliveries, for example, the reorder point leadtime usually falls in the middle of the schedule of deliveries so some items arrive before the leadtime and some after. For Method 1 items, which are not supposed to be delivered incrementally, delivery leadtimes still may not match reorder point leadtimes because reorder point leadtimes are not always based on the actual month of delivery. (This potential flaw in Method 1 implementation is discussed further in Chapter 7.)

In using the data in Table 3-1 and the associated distribution, we are assuming that the basic characteristics of C&T supplier responsiveness are described by those data and that those characteristics do not change over time. The stability from one month to the next in the percentage values within each period in Table 3-1 supports those assumptions. However, the new delivery schedules being introduced by the C&T Directorate are supposed to improve supplier responsiveness. If they do, the delivery delay distribution will need to be updated. In the meantime, the simulation allows the user, through the use of a control knob, to adjust the variability reflected in the delivery delay distribution. The PLT control knob, which can be set to any nonzero value, changes the scale over which the delay distribution is defined (see Figure 3-3). With a setting of 1.0, the distribution is unchanged and results in deliveries that are 55 days late on average. With a setting of 0.5, deliveries will be 27.5 days late on average, while a setting of 2.0 will make them 110 days late on average.

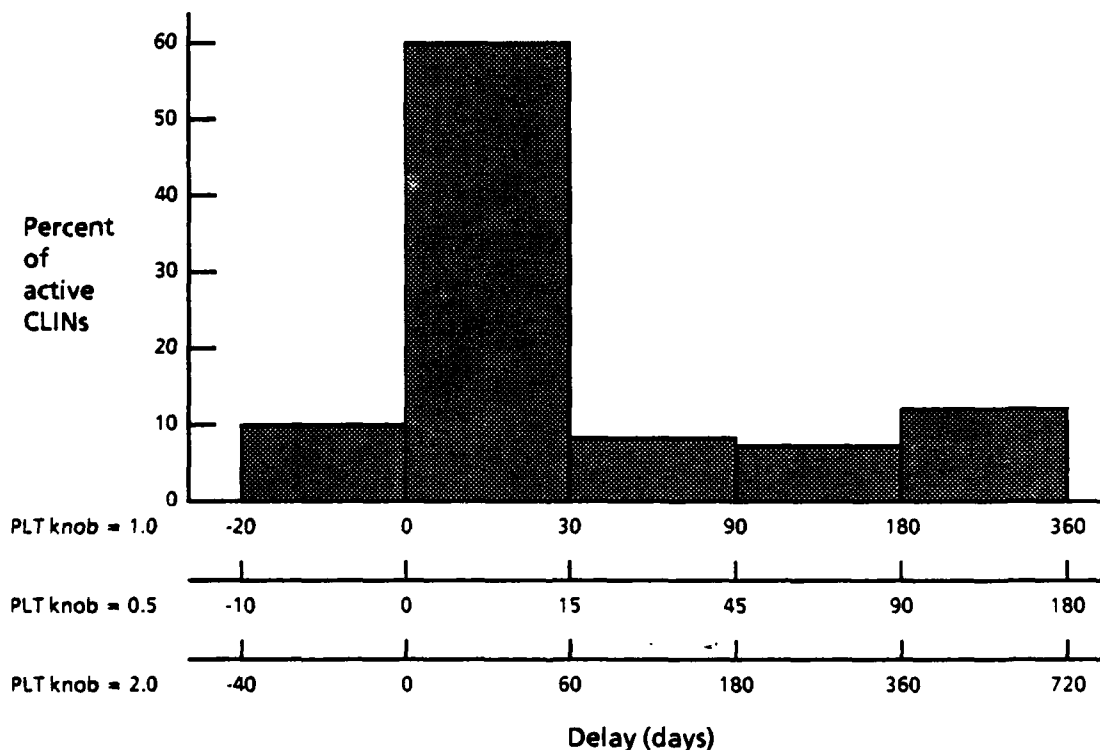


FIG. 3-3. EFFECT OF THE PLT CONTROL KNOB SETTINGS

The PLT control knob allows a user to tailor leadtime variabilities. If, for a given PGC, the user has an idea about how many days late deliveries are likely to be,

the PLT control knob can be set so that the average delay matches the estimated lateness. This converts the user's estimate of a likely event into a mean value about which the simulation will operate. This feature of the simulation can be used to examine the effects *if* the new delivery schedules reduce leadtime variabilities.

A final point on the simulation of supplier responsiveness involves the deliberate "coupling" of reorder point leadtimes with delivery leadtimes. In the C&T simulation, delivery leadtimes, which identify the points in simulated time about which deliveries will take place, correspond to the leadtimes used to set reorder points. This was done deliberately in order to approximate the effect of the "needs test" procedure being implemented as part of the new C&T delivery policy.

The new DLA C&T Directorate policy for delivery schedules for multi-item PGCs is that for a given replenishment order, items shall be classified as X, Y, or Z according to how the item's order amount compares with the total amount of the order. In a multi-item PGC, order amounts can be different from full order quantities because items can be reordered before they reach their reorder points. Thus, items that are classified X, Y, or Z when the reorder point is set can have a different classification when a delivery schedule is made. Delivery leadtimes were deliberately decoupled from reorder point leadtimes to accommodate delivery schedules that suppliers will, theoretically, be better able to provide. However, the new delivery policy also calls for a needs test. Given projected demand, if a planned delivery schedule generates a need, i.e., requires the use of safety-level stocks, the delivery schedule must be modified to avoid that problem.

The effect of the needs test is to move scheduled deliveries back towards what they would be if reorder point leadtimes were used to make the schedule in the first place. To approximate the effect of the needs test, therefore, the simulation couples delivery and reorder point leadtimes. (So that "X" items for reorder point purposes are always "X" items in the delivery schedule, for example). By doing so, the simulation is able to approximate — usually within a month — what delivery schedules would look like after application of the needs test.

This chapter has described each of the four aspects of C&T inventory management — requirements forecasting, inventory control, customer demand, and supplier responsiveness — and how each is simulated. As an analysis tool, the C&T simulation is best suited to questions that relate to these four activities.

## CHAPTER 4

### OUTPUT REPORTS

In this chapter, we describe the output reports and the graphic displays the C&T simulation generates. We also address the statistical aspects of simulation results in a discussion of confidence intervals and warm-up periods. The titles and abbreviations of specific output variables are shown in capital letters and enclosed in brackets throughout the chapter, e.g., [TITLE].

The C&T simulation produces three output reports after each model run: a Summary PGC Report, an Aggregate PGC Report, and a Detail Trace Output Report. It can also produce a PGC Net Stock histogram.

#### THE SUMMARY PGC REPORT

The Summary PGC Report (Exhibit 4-1) summarizes key inventory performance statistics at the PGC level. The screen in Exhibit 4-1 appears on the PC monitor at the end of every simulation run and is also written to the Detail Trace Output Report.

```

=====
SUMMARY PGC REPORT
=====
(PGC NO. 1672 RUN ID 0)
PGC NAME SHIRT,MAN'S NSNs 3 COST 7.25 ORDERS/YR 2.33
=====
TIME WGT BO ===== AVAILABILITY ===== DEMANDS/YR ==
TOT RTC TOT RTC TOT RTC
REQUISIT. 31.7 1.8 80.92 81.28 3167 187
UNITS 2876.9 1237.9 78.53 78.28 267713 118870

AVERAGE:===== STOCK ===== ONORDER ===== SAFETY LEVEL =====
UNITS 127021 356387 94664
DOLLARS 920899 2583804 686311

===== CALIBRATION/VALIDATION INFORMATION =====
TIME.V(YR) 3.0 SIM (YRS) 3.0 WARMUP 0 (REVIEW 2 DEMAND 1 DAYS)
PGC.BO %CI/MEAN AVE NET STOCK %OR/OH+OR % FORE/DEMD YR FORCST
34 0. 121984 73.72 94.13 252009

```

EXHIBIT 4-1. SUMMARY PGC REPORT

The [ORDERS/YR] entry is the average number of replenishment orders for the PGC placed with suppliers per year, computed over the number of simulated years in the run. This output is a good indicator of whether the simulation is matching real-world behavior for the PGC.

Time-weighted backorders [TIME WGHT BO] refers to the average number of outstanding backorders present in the system over time. [At any given time,  $t$ , an inventory system will have some number of outstanding backorders,  $b(t)$ , to customers (perhaps zero). The average value of  $b(t)$  over time is time-weighted backorders.] For DoD supply systems, time-weighted backorders [sometimes called expected backorders (EBOs) or average backorders on hand] represent the single most important measure for gauging how supply customers are being supported.

The [AVAILABILITY] entry reflects cumulative supply availability rates over the course of the run. All backorder, availability, and [DEMANDS/YR] statistics are reported for requisition demand and unit demand, considering both overall demand [TOT] and Recruit Training Center [RTC] demand.

The average values [STOCK] and [ON ORDER] are time-weighted averages of stock on hand and stock on order. The average [SAFETY LEVEL] entry reflects the quantity and value of safety level carried in the system for the PGC. It is computed by multiplying the safety level in months for the NSN (fixed or variable) by the underlying average monthly forecast for the NSN and then summing over all NSNs in the PGC.

The calibration/validation information at the bottom of the Summary PGC Report presents additional information about a run. The total length of time simulated, including the warm-up period, is listed next to [TIME.V(YR)]. The length of time over which statistics were accumulated is [SIM(YRS)], and the length of the warm-up period in years appears next to [WARMUP]. The parenthetical information following the [WARMUP] entry states how often reorder points are checked in the simulation (e.g., [REVIEW 2] means reorder points are checked every other day) and how often demands are generated (e.g., [DEMAND 1] means demands are generated daily).

The [PGC.BO] entry is a sampling estimate of the average number of outstanding requisition backorders. It is obtained by averaging values of outstanding requisition backorders taken in "snapshots" over the course of the run.



The longer the run, the closer the value of [PGC.BO] will match the accumulated value of [TIME WGHT BO] for requisition backorders.

The [% CI/MEAN] entry is related to a 95 percent confidence interval estimate of time-weighted requisition backorders. The confidence interval estimate is centered on the [PGC.BO] point estimate. The [% CI/MEAN] entry is the ratio of the radius of the interval estimate to the point estimate, expressed as a percent. [% CI/MEAN] provides a measure of the relative precision of the result for outstanding requisition backorders. A large percentage value for [% CI/MEAN] indicates considerable relative variability about the average number of outstanding backorders. If the number of average outstanding backorders is small, it is possible for [% CI/MEAN] to be large even though the interval estimate for backorders may be narrow in absolute terms. For example, an interval estimate of  $10 \pm 5$  outstanding backorders on average may be an acceptably precise result, even though the [% CI/MEAN] ratio is 5/10 or 50 percent.

The [AVE NET STOCK] entry is a sampling estimate of the average amount of on-hand stock minus backorders for the PGC. It is the mean for the PGC Net Stock histogram, which is discussed further later.

The [% OR/OH + OR] entry is the ratio of average on-order stock (in units) to the sum of on-hand and on-order stock (in units). It is often a more useful validation measure than backorders because backorders may be relatively rare.

The [% FORE/DEMD] entry is the ratio of average annual forecasted unit demand (as it occurred in the simulation) to the annual average of actual demand (as it occurred in the simulation). In Exhibit 4-1, for example, 94.13 percent is the ratio of the average annual forecast [YR FORCST] of 252,009 units to the [DEMANDS/YR] average of 267,713 units actually demanded. Because of left-handed truncation effects in normal distributions (especially when item MADs are very large relative to the mean forecast), the [% FORE/DEMD] ratio is often less than 100 percent even for long runs.

## THE AGGREGATE PGC REPORT

Although the C&T simulation runs one PGC at a time, users may want to see the results of several runs on the same PGC, or – even more likely – the results of

one run on several different PGCs. The Aggregate PGC Report is designed to support such multiple-run/multiple-PGC analyses.

Exhibit 4-2 shows an Aggregate PGC Report containing the results of the same run done on three different PGCs. The [TOTAL] line shows that for the system of three PGCs, the average number of on-hand backorders for the system is 2,886 unit backorders and 155 requisition backorders. The [TOTAL] figures for system requisition supply availability show that the demand-weighted average of the three PGC availabilities is 98 percent – both overall and considering requisition supply availability to RTCs alone. The [UNIT AMD/100] column shows average monthly demand in 100s of units, while the other demand columns show average number of requisition demands per month – both overall and from RTCs.

***** AGGREGATE PGC REPORT *****										
3 PGC RESULTS IN SUMMARY (FILE ALLPGCS.DAT)										
PGC REQT /ID	----AVERAGE--		--%REQT--		-----STOCK LEVELS-----			-----DEMAND-----		
	BOH	SUP AVAIL			(\$ 1,000,000 )			UNIT	REQT	RTC
	UNIT	REQT	ALL	RTC	ONHAND	ONORDER	SAFETY	AMD/100	AMD	AMD
1834	1853	106	96	97	88	132	54	740	1220	38
1765	282	38	99	98	119	189	69	224	1864	96
1672	751	11	97	97	10	25	7	211	257	15
-----										
TOTAL	2886	155	98	98	217	346	130	1175	3341	149
KEY: AMD = AVERAGE MONTHLY DEMAND										
REQT = REQUISITIONS										
ALL = ALL CUSTOMERS (PICS)										
RTC = RECRUIT TRAINING CENTERS										
BOH = BACKORDERS ON HAND										
SUP AVAIL = SUPPLY AVAILABILITY										

EXHIBIT 4-2. AGGREGATE PGC REPORT

When the Aggregate PGC Report is used to summarize the results of several different runs on the same PGC, the [TOTAL] line does not appear and the [PGC/ID] column contains the run ID number rather than a listing of PGC numbers. The user controls the configuration of the Aggregate PGC Report through Query 6 (see Chapter 6).

## **THE DETAIL TRACE OUTPUT REPORT**

The Detail Trace Output Report contains a detailed audit trail of all the simulation activities, as well as input data and output reports. Specifically, the report contains four sections: Input Data, Simulation Data Description, Simulation Over Time, and End of Run: PGC Results.

Trace output changes slightly based on user responses to model queries. A short-duration simulation produces extensive and detailed trace information. For a long-duration simulation, the volume of information in the trace is automatically reduced. Appendix B contains an example of the Detail Trace Output Report for a long-duration simulation, the "demonstration" PGC (3 NSNs).

### **The Input Data**

The Input Data section of the Detail Trace Output Report reproduces the information in the MPT011 and SSCF input files.

### **The Simulation Data Description**

The Simulation Data Description section in the Detail Trace Output Report contains the data used by the simulation. Some of those data are taken directly from input files, while other data must be combined and converted to a form required by the model. The following paragraphs describe the five data tables in the section.

The DELIVERY MATRIX FOR X, Y, AND Z ITEMS table displays the percentages that show how the total order is delivered over the delivery period. Percentages are by item classification (X, Y, Z) and are calculated by the model based on the method of delivery, the delivery percentages at the PGC level, and the XYZ item percent cutoff.

The SUMMARY OF MONTHLY TOTAL FORECAST AND C&T 36 MONTH POI FORECASTS table displays the total average monthly forecast [TOTAL AMF], the POI average forecast from the SSCF data [POI AMF], and the POI standard deviation [POI STD] obtained from the NSN input forecasts in the SSCF input file.

The CURRENT CTREQ.MAT table displays the model-generated POI forecasts by NSN for the first 90 months. The table is generated from a normal distribution with the mean and standard deviation displayed in the previous table.

The CURRENT CTREQ.MAT table is displayed only for short-duration runs and is not shown in Appendix B.

The MODEL OPTION ASSUMPTIONS table displays the user-entered responses to the interactive query session.

The table, KEY VARIABLES USED IN RUN table displays input data and model-generated data. The model-generated data are the RTC cutoff [RTC CUT], the standard deviation of demand divided by the average monthly total forecast expressed as a percent [%SD/AMF], and the item type [XYZ] where X is 1, Y is 2, and Z is 3.

### The Simulation Over Time

The Simulation over Time section of the Detail Trace Output Report displays inventory status over simulated time. Information is recorded every year in a short-duration run and at the halfway and end points of a long-duration run.

The BEGINNING OF MONTH table displays the starting inventory levels for the month by NSN: the monthly demand and forecast, the procurement cycles, reorder point, stock on hand and on order, and the unit backorders (UBO) and requisitions backorders (RBO).

The END OF MONTH DATA table displays cumulative statistics up to the current time by NSN: the average requisition size [APS.SM] and the average time interval in days between requisitions [INTRVL]; the average monthly forecast [AMF] and the ratio of forecast to actual demand [FOR/DD]; the on-hand and on-order inventory; the on-order inventory as a percentage of the on-hand plus on-order inventory [%O/O]; and the on-order inventory divided by AMF [OR/F], the on-hand inventory divided by AMF [OH/F], and the war reserve inventory divided by AMF [WAR]. The latter five variables are generated to facilitate comparison of model results with Flash Report results (discussed in Chapter 5).

The next table displays average backorder delay in days [AVBOD], the demands per year [DEM/YR], time-weighted backorders [EBOs], and the demand-weighted supply availability [FILL RATES] by NSN. The left side of that table shows that data at a requisition level and the right side, at a unit level. The table

also distinguishes between all customers [TOT] and Recruit Training Center [RTC] customers.

For long-duration runs, a line is printed [QUICK] every 2 years displaying a quick approximation of the confidence interval estimate for requisition backorders so the user can see how average backorders are varying with time. The following PGC statistics are printed: the year [YR], the mean requisition backorders up to this time [MEAN], the current net stock [NETSTOCK], the 95 percent confidence interval radius [CI], and the CI radius divided by the MEAN expressed as a percent [%CI/AVE]. The QUICK line can be printed by NSN, if desired. As currently configured, it contains PGC-level statistics. The term QUICK NSN 1 indicates PGC-level statistics if no other NSNs appear.

For short-duration runs, the simulation displays three additional tables, all with NSN-specific information. The first table, Breach Time, displays inventory conditions at the time of the breach: size of order [ORDER]; on-hand stock; on-order stock; reorder points; and backorders [BO] at a unit level [U], at the requisition level [REQ] and for recruits [RC]. The second table is printed each month with the monthly demand [DEMAND-MONTH] and the monthly forecast [FORCST-MTH]. The third table, Deliver Order, displays when the order is received, the delivery month [SCH MTH] in the matrix schedule, and the size of the incremental delivery [QUANTITY].

#### **End of Run: PGC Results**

The End of Run: PGC Results table of the Detail Trace Output Report displays several tables summarizing the results of the simulation at the PGC level. The first table, STATS FOR RUN, displays information used by the model to calculate a confidence interval. That information includes the following: the time interval in days between samples [INTVL], the number of samples [BLOCKS], the number of years of sampling (YRs), the sample mean [MEAN], the sample variance [VAR], the covariance of the sample mean [2COVAR/N], the variance of the sample mean [MEAN.VAR], the 95 percent confidence interval [C.I. 95%], and the ratio of the CI to the sample mean expressed as a percent [% CI/MEAN]. Those variables are discussed in the "Confidence Interval" section at the end of this chapter.

The next End of Run: PGC Results tables are duplicates of the PGC Summary Report table (Exhibit 4-1) and the PGC Aggregate Report (Exhibit 4-2) for the current PGC.

#### PGC NET STOCK HISTOGRAM

After each PGC run, the PGC Net Stock histogram is displayed on the screen (see Exhibit 4-3). Net stock at a point in time is defined as on-hand inventory minus the backorders summed across all NSNs in the PGC. The histogram shows how net stock levels for the PGC vary over time.

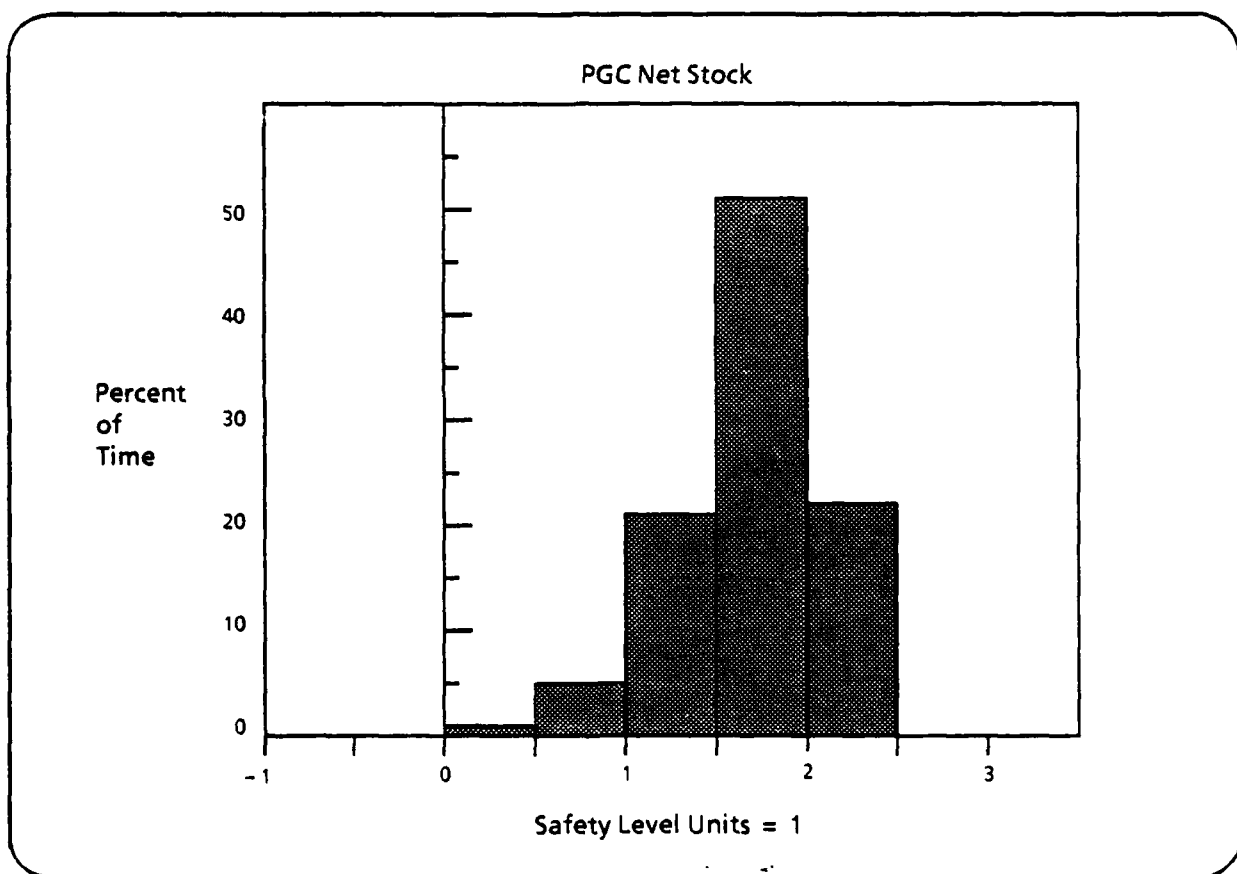


EXHIBIT 4-3. PGC NET STOCK HISTOGRAM

The histogram intervals represent safety-level units of stock for the PGC. The "1" on the X axis corresponds to the total units of safety stock summed across all NSNs in the PGC. For a "bag-item" PGC (are items initially issued to recruits), for

example, one unit of safety level represents approximately 4.5 months of PGC demand. A value of 2 or 3 on the X axis equals approximately 9 or 13.5 months of demand, respectively. The purpose of the PGC Net Stock histogram is to display how often net stock for the PGC is above the PGC safety level, in the safety level, or negative (indicating total backorders exceed total on hand for the PGC). The histogram reflects *net stock* for the PGC. Positive net stock does not imply that no backorders exist — only that total stock on hand exceeds total stock on backorder. The purpose of the histogram is to give picture of supply system status over time for the PGC as a whole.

## THE STATISTICAL ASPECTS OF SIMULATION OUTPUT

In this section, we describe statistical aspects of the simulation output — how confidence intervals are calculated and the reason for removing the impacts of a warm-up period.

### Confidence Intervals

Simulations give sample results — either through replication or, as is the case with the C&T simulation, through the use of long runs. For long runs, the precision of the output depends on the length of simulated time the model runs. The longer the simulation, the larger the sample of information and the more precise the results.

C&T simulation output includes a 95 percent confidence interval estimate of the average number of outstanding requisition backorders for the system. Given data on customer demand, supply responsiveness, and the quantitative levels used, the C&T system will calculate an expected backorders value for each PGC. A 95 percent confidence interval estimate means we are 95 percent confident that the interval contains the true expected backorders for the system. In general, the longer the simulation runs, the smaller the confidence interval. Confidence interval estimates of backorders are better than point estimates alone because they capture the degree to which outstanding backorders can vary about their average value.

A 95 percent confidence interval estimate of the mean is defined as the sample mean plus or minus 1.96 times the square root of the variance of the sample mean. When obtaining samples through long runs, it is necessary to account for correlation of sample values from one block to the next. For the correlated values from a long

run, the variance of the sample mean is the sum of the sample variance plus the sample covariance.<sup>1</sup>

The simulation provides a confidence interval estimate for requisition backorders for each PGC run. A quick approximation of the confidence interval is calculated every 2 years (labeled [QUICK] in the Detail Trace Output report) and recorded along with the sample mean, net stock, and the ratio of the confidence interval radius to the sample mean. The first table of the End of Run PGC Results section of the Detail Trace Output Report displays the actual confidence interval estimate as well as the sample mean and variance, the covariance and variance of the mean, and the ratio of the confidence interval (CI) radius to the mean, expressed as a percent.

The CI-to-mean ratio is the key estimate of precision in determining how long to run the simulation. If the ratio is large, 200 or 300 percent, the simulation results are correct only within a factor of 2 or 3 and a longer simulation in years may be needed. However, if the CI-to-mean ratio is 20 percent or less, the simulation results are fairly precise. The user must make the tradeoff between precision and run time in applications.

A few hundred years of simulated time for a PGC can usually be run overnight. Such runs usually yield CI-to-mean ratios in the tens-of-percent range. Hard and fast rules on simulation run times do not exist. Appropriate run time depends on the characteristics of the PGC, the time a user is willing to wait for results, and the degree of precision required. For policy analyses (like the C&T VSL question), we recommend a minimum run length of 200 to 400 years.

### Warm-up Periods

A final statistical consideration is the warm-up period — the initial period of time affected by the starting conditions of the simulation. At the start of the C&T simulation, each NSN is assigned on-hand stock equal to its reorder point, has no backorders, and has no stock on order. To remove any bias introduced by those starting conditions, the simulation is run 5 years (the warm-up period) before statistical estimates of the variables are taken. We assume that after 5 years,

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<sup>1</sup>Covariance calculations are based on covariance equations in Donald Gross and Carl M. Harris, *Fundamentals of Queueing Theory*, John Wiley & Sons, Inc., 1974, p. 418.



inventory conditions (backorders, stocks on hand, and stocks on order) have reached levels that no longer reflect the initial bias of the starting conditions.

The simulation for long runs was designed with one warm-up period to save processing time. Removal of the warm-up period each time in a sequence of repetitive runs wastes processing time. With a long run, the warm-up period need only be removed once.

## CHAPTER 5

### VERIFICATION AND VALIDATION

#### INTRODUCTION

This chapter reports the results of some verification and validation tests performed on the C&T simulation. In it, we present evidence that the simulation is working as intended (verification) and that it can produce results comparable to historical performance by C&T (validation).

Verification and validation testing has been performed continually throughout model development. Demonstrations of the simulation in prototype form, hands-on trials, and a formal validation session with DLA personnel have all been part of the development effort as a way to obtain user guidance and ensure that simulated procedures match actual C&T practice. This chapter will quantify and summarize some of the key aspects of the verification and validation testing.

In this chapter, we show that input data are read and used correctly, SAMMS inventory control procedures are followed, and on-hand and on-order stock levels generated in the simulation are plausible. We compare simulation results with actual C&T results, discuss how and where they match, and explain areas in which they do not. Some of the verification and validation data extracted from the simulation in this chapter were obtained through the use of approximately 30 trace switches embedded in the model source code. Those switches allow individual operations and procedures to be independently exercised, listed, and checked.

We examined data for three PGCs in the verification and validation effort: man's coat (PGC 1765), woman's shirt (PGC 1671), and men's and women's gloves (PGC 1834). The actual C&T inventory data for the three PGCs is taken from two sources: Flash Reports and Never-Out Item Reports. Flash Reports from 1986 and 1988 were used to determine average monthly forecasts (AMF), average monthly customer demand (AMD), peacetime acquisition objectives (AO), on-order stock (O/O), and peacetime on-hand stock (POS). The AO, O/O, and the POS levels are expressed in months of demand (units of stock divided by AMF). The Never-Out Item Reports list the requisition backorders present at the end of the month. The

Never-Out Item Reports used are for 14 months in 1986 and 1987. Flash and Never-Out Item Reports are produced monthly and contain NSN-level information.

We generated simulation results based on assuming six equal incremental deliveries for each NSN. That simulation reflects the basic mode of operation for C&T deliveries prior to the implementation of new delivery policies. Matrix delivery schedules were not in place when the historical Flash and Never-Out Item data were compiled.

## VERIFICATION

Verification ensures that simulation code is working as intended. In this section, we discuss checks made to ensure that proper input data are used, SAMMS inventory procedures are followed, and plausible results are produced for on-hand, on-order, and backorder estimates. While we performed verification analyses on all three PGCs, the following discussion is limited to the woman's shirt PGC (1671), which contains 21 NSNs.

### Verification of Forecasts

Are requirement forecasts (including both POI and QFD components) captured and used correctly in the simulation? Table 5-1 displays AMF data for the 21 NSNs in the woman's shirt PGC. The table lists the AMF data from the February 1988 Flash Report (88060) and the 12-month AMF captured from the February 1988 SSCF Report. The ratio of the two forecasts is displayed in the fourth column. All ratios are close to 100 percent, which suggests that the simulation is using the correct SSCF input, reading the data correctly, and combining the POI and QFD forecasts correctly to obtain the total AMF. The two forecasts do not match exactly because averages were taken over slightly different time periods.

As discussed in Chapter 3, the simulation generates monthly forecasts from a normal distribution. The mean of the distribution is the average of the 36-month POI forecast in the input data plus one-third of the QFD forecast. Column 5 of Table 5-1 – the simulation average – displays the AMF after 100 years of simulated forecasts. The simulation values are close to Flash Report monthly AMFs as illustrated by the ratios in Column 6 of Table 5-1; that agreement indicates the simulation generates the proper AMF over the course of simulated time.

**TABLE 5-1**  
**FORECAST COMPARISONS**  
**(Woman's shirt PGC)**

- 1 - NSN	- 2 - Flash 88060	- 3 - SSCF 1/88	- 4 - Ratio (%) Flash/SSCF	- 5 - Simulation average	- 6 - Ratio (%) Flash/SIM
1	18	19	96	18	100
2	42	43	97	43	98
3	14	17	82	17	82
4	171	170	101	165	104
5	132	133	99	130	102
6	39	40	98	39	100
7	351	351	100	342	103
8	244	244	100	237	103
9	96	95	101	92	104
10	549	546	100	534	103
11	395	394	100	383	103
12	153	151	101	146	105
13	289	288	100	281	103
14	989	987	100	961	103
15	209	207	101	201	104
16	148	149	100	145	102
17	533	533	100	519	103
18	156	156	100	152	103
19	91	90	101	88	103
20	131	131	100	128	102
21	49	53	93	52	94
PGC	4,799	4,797	100	4,673	102

### Verification of SAMMS Procedures

Are peacetime acquisition objectives (AO) calculated correctly? Though we did not separately test individual SAMMS factors produced in the model, we did test the *sum* of several critical SAMMS factors: the safety level, the administrative and production leadtime, and procurement cycle period (PCP).

For the woman's shirt PGC, all 21 NSNs have safety levels of 4.5 months and total leadtimes of 15.7 months of demand. The PCP is NSN-specific and is displayed

in Column 2 of Table 5-2. Columns 3 and 4 display the AOs from the simulation and the Flash Report, respectively. The two sets of AOs match exactly for most NSNs, differing only slightly on four items. This suggests that the simulation is calculating safety level, production leadtime (PLT), administrative leadtime, and PCP correctly. The only explanation for the four NSNs that fail to match is that manual overrides were present in the SAMMS data picked up in the Flash Reports.

**TABLE 5-2**  
**ACQUISITION OBJECTIVES AND STOCK LEVELS**  
(Woman's shirt PGC in months)

- 1 -  NSN	Acquisition objective				Average asset position (AP)			- 9 -
	Simulation		- 4 -  Flash AO	- 5 -  Delta Flash - SIM	- 6 -  Adjusted AO	- 7 -  OH + OR - BO SIM	- 8 -  Ratio (%) AO/AP	On- order stock
	- 2 -  PCP	- 3 -  AO						
1	12	32	32	0	31	28	109	18.2
2	7	27	28	- 1	26	27	96	17.9
3	12	32	32	0	31	29	107	18.0
4	6	26	26	0	25	26	95	17.9
5	6	26	26	0	25	24	102	18.0
6	8	28	28	0	27	26	102	18.1
7	6	26	26	0	25	25	99	17.8
8	6	26	26	0	25	25	101	17.9
9	6	26	26	0	25	25	101	18.1
10	6	26	27	- 1	25	25	100	18.0
11	6	26	26	0	25	25	101	17.9
12	6	26	26	0	25	24	101	18.0
13	6	26	27	- 1	25	26	96	18.0
14	6	26	26	0	25	25	100	17.9
15	6	26	26	0	25	25	101	17.9
16	6	26	26	0	25	25	100	18.0
17	6	26	26	0	25	25	100	17.9
18	6	26	26	0	25	25	101	18.0
19	6	26	27	- 1	25	25	99	18.0
20	6	26	26	0	25	25	100	18.0
21	7	27	27	0	26	26	100	18.0
PGC					25	25	100	17.9

## Verification of Simulated Stock Levels

Do stock levels generated by the simulation behave consistently and correctly? Given the input data and the rules the C&T Directorate follows, we can make general estimates on what the stock levels should be. In this section, we examine the consistency of total stock levels, on-order stock, and negative stock (backorders) from an inventory-theoretic perspective.

The AO may be thought of as the maximum asset position (on order plus on hand minus backorders) that can occur at any time in the simulation. The average asset position for an NSN should be less than the AO by an amount dependent upon the PCP and the average number of replenishment orders per year. For example, the asset position for an item with a 6-month PCP and averaging two orders per year would usually fluctuate between the AO and the AO minus 6 months. An approximate average asset position average would, therefore, be the AO minus 3 months. For the woman's shirt PGC, an average of 4.45 orders per year are placed, so the adjustment to the AO is 1.34 months for NSNs with a PCP of 6 months. The AO minus that adjustment should approximate the average asset position in the simulation. Table 5-2 displays each NSN's AO minus the 1.34-month adjustment, the average asset position generated by the simulation, and the ratio of the two levels. For most NSNs, the adjusted simulated AO agrees with the simulated asset position. This is evidence that stock levels in the simulation are being correctly computed.

Another test is to compare on-order stocks (in months of demand) to leadtime. In general, the amount of stock on order should agree with the average leadtime for the item. In the simulation, the leadtime for the woman's shirt PGC is 15.7 months. The average supplier delay over the course of the simulation is 1.8 months. Thus, the total leadtime is 17.5 months. The last column in Table 5-2 displays the average on-order stock in months from a 100-year run. For the 21 NSNs in the PGC, on-order stock ranged from 17.8 to 18.2 months, agreeing well with the expected value of 17.5 months.

Are backorder calculations correctly performed? Time-weighted backorders are the most important estimate of inventory performance. They are also the most difficult measure to verify and validate in the simulation because backorders tend to occur infrequently and are usually small in relation to demand and asset position.

They tend to occur only under extreme conditions. One way to verify backorder estimates is to calculate them in two different ways and test the results for agreement. The first way is to track each backorder as it occurs and record how long it lasts. From that information, it is possible to compute the time-weighted average of outstanding backorders. The "accumulate" feature in SIMSCRIPT computes that average automatically. The second way is to sample backorders at constant intervals throughout the simulation and compute the sample average. Both approaches yield nearly identical results (within 1 or 2 percent) for unit and requisition average backorders.

The preceding verification evidence indicates that the simulation code is performing as intended.

## **VALIDATION**

This section compares simulation results with historical C&T inventory information from Flash and Never-Out Item Reports to obtain preliminary evidence on the validity of the simulation. For definitive validation, we must examine more PGCs, with more historical data, over longer periods of time. Nevertheless, the results presented here suggest the simulation is able to approximate real-world C&T performance at the PGC level. We start with a discussion of how well the simulation is able to reproduce real-world forecasting and demand processes.

### **Forecast and Demand Validation**

In this section, we focus on trends in historical forecasts and actual demands over time. We compare historical forecasts with actual demands and examine how well the simulation reflects forecast and demand trends. We also suggest steps that can be taken to better integrate and improve simulation results and data collection efforts.

#### ***Historical Forecasts and Demands***

A key observation of the validation effort is that all three PGCs studied exhibit significant decreases in AMF from 1986 to 1988. For the woman's shirt PGC, the AMF at the PGC level decreased from 5,641 in 1986 to 4,321 in 1988, making the 1986 PGC forecast 131 percent of the 1988 forecast. In other words, 1988 forecasts were 31 percent smaller than 1986 forecasts. The gloves and coats PGCs showed similar trends although the percentage decline is approximately half that of the

woman's shirt PGC. This declining forecast trend is even more pronounced at the NSN level. Table 5-3 displays the 1986-to-1988 AMF ratios for each size (NSN) of woman's shirt. Some ratios are as great as 460 percent.

**TABLE 5-3**  
**FLASH FORECASTS FOR 1986 AND 1988**  
**(Woman's shirt PGC in units)**

NSN	AMF		Ratio (%) 1986/1988
	Average 1986	Average 1988	
1	52	17	302
2	145	45	324
3	67	14	468
4	146	165	88
5	419	124	337
6	173	37	464
7	278	297	93
8	531	220	242
9	238	89	267
10	313	452	69
11	801	374	214
12	340	131	260
13	279	260	107
14	619	869	71
15	442	188	235
16	80	165	48
17	265	472	56
18	312	142	219
19	47	98	47
20	67	114	59
21	32	47	66
PGC	5,641	4,321	131

Like AMF, the AMD also declined from 4,731 in 1986 to 3,565 in 1988, making a 1986-to-1988 ratio of 132 percent. The gloves and coats PGCs showed similar declines, but the ratios were closer to 100 percent. The interesting aspect of the AMD trend is how it compares with the AMF trend. For all three PGCs, the AMF-to-AMD ratios from 1986 to 1988 were greater than 100 percent both at the PGC level



and for the majority of NSNs. A general tendency in the POI system to overforecast customer demand is also noted in a 1985 DLA study,<sup>1</sup> that reported 61 percent of the 300 POI PGCs studied exhibited overforecasted demand.

The tendency to overforecast is consistent over time at the NSN level. The 1986 AMF-to-AMD ratios strongly correlate with those for 1988. For the woman's shirt PGC, the sample correlation coefficient is 0.97. The man's coat PGC also exhibits a strong AMF-to-AMD ratio correlation over time, with a sample correlation coefficient of 0.83. The correlation coefficient for men's and women's gloves is lowest at 0.34.

In summary, three key observations can be made about historical AMFs and AMDs for the three PGCs examined: (1) the AMF declined significantly from 1986 to 1988, (2) the tendency is to overforecast customer demand, and (3) the ratios of AMF to AMD are correlated over time at the NSN level. As we discuss next, these three conditions must be taken into account in attempting to validate the simulation.

### ***Simulation Results***

Regarding the problem of trends, the model cannot simulate a trend in forecasts similar to that which occurred from 1986 to 1988. The current forecasting process generates a requirements array that rolls forward in simulated time but is still always a reflection of the single requirements forecast in the input data. To simulate trending forecasts it would be necessary to develop a "short-run-with-replications" version of the simulation. It is not clear what such a capability would accomplish, however. Presumably DLA is interested in simulating forecasting trends in order to determine how they affect supply performance. Simulation, however, is not the best tool for measuring such transient effects. A better approach would be to analyze historical performance data from periods for which forecast trends existed and from that analysis develop empirical rules on how trends in forecasts are likely to affect stockage requirements and performance in the future.

The user can adjust the simulation to mimic the tendency to overforecast. At the PGC level, the simulation has a demand control knob to adjust the AMD to make it less than or greater than the AMF. For the woman's shirt PGC, the 1988

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<sup>1</sup>S. Orchowsky, *Report on Analysis of the Program Oriented Item System for Forecasting Clothing Items*, Operations Research and Economic Analysis Office, Headquarters DLA, Jan 1985.

AMD-to-AMF ratio is 0.82 (3,565 divided by 4,321). To incorporate this overforecast tendency into the simulation, the demand knob may be set at 0.82. This adjustment affects all NSNs in the PGC equally, so that the AMD on average will be approximately 18 percent less than the AMF for the PGC as a whole.

The third observation about historical forecasts and demands, that AMD-to-AMF ratios are correlated over time, suggests that the demand-generating process in the simulation could possibly be improved by incorporating forecasting bias in the form of empirical forecast-to-demand ratios. This suggestion is discussed further in Chapter 7.

Before comparing simulation results to Flash Report values at the NSN level, another point must be made about simulation results alone. Table 5-4 displays the AMF and the AMD generated by the simulation for the woman's shirt PGC with a demand knob setting of 1. Table 5-4 also displays the simulated AMF-to-AMD ratio. The table shows the simulation may tend to underforecast demand (AMF-to-AMD ratios less than 100 percent).

An underforecast bias exists in the simulation because demands are drawn from a normal distribution that has as its mean the monthly forecast and  $(1.25 \times \text{MAD})$  as its standard deviation. Underforecasting occurs when an NSN has a very large MAD in relation to its mean. The larger the MAD, the greater chance that the value drawn from the normal distribution will be negative. Since negative demands do not make sense, the simulation truncates all negative values and sets them equal to 1. That truncation unbalances the symmetry of the normal distribution, and the AMD becomes larger than the AMF. Thus, when MAD is large relative to the mean forecast, the simulation has a tendency to underforecast demand.

### ***Mean Absolute Deviation***

The preceding discussion raises the separate and important question: why are MADs for POI items so large? We believe the problem is that for POI items, MAD is not keeping pace with changing forecasts. Table 5-3 shows that from 1986 to 1988, forecasts declined significantly. For NSN 3, for example, the 1986-to-1988 ratio is 468 percent. The MAD in the SSCF input data for NSN 3 is 36.3. The absolute deviation, however, between the AMF and the AMD for 1986 and 1988, respectively, is 18 and 6. At 36.3, the NSN 3 MAD is much greater than it should be based on

**TABLE 5-4**  
**SIMULATION FORECASTS AND DEMANDS**  
**(Woman's shirt PGC in units)**

NSN	AMF	AMD	% AMF/AMD
1	18	25	74
2	43	59	72
3	17	28	60
4	165	167	99
5	129	164	79
6	39	55	71
7	342	342	100
8	236	270	88
9	92	114	81
10	535	538	99
11	382	421	91
12	146	181	81
13	282	284	99
14	955	959	100
15	200	226	89
16	146	155	94
17	520	524	99
18	151	167	91
19	88	95	93
20	127	132	97
21	52	58	90
PGC	4,667	4,964	94

experience in 1986 and 1988. When the MAD of 36.3 is used in the simulation, the demands for NSN 3 are drawn from a normal distribution that has a standard deviation 2.7 times larger than the mean (AMF). As a result, NSN 3 is the most underforecasted NSN in the PGC (AMF-to-AMD ratio of 60 percent in Table 5-4).

MADs can be large when current deviations are small because of the way MAD is calculated. The formula for MAD weights and averages the deviations (forecast minus demand) from all previous time periods:

$$MAD(t) = \sum_{i=0}^{t-1} \text{ALPHA} \times (1 - \text{ALPHA})^{t-i} \times [|AMF(i) - AMD(i)|], \quad [\text{Eq. 5-1}]$$

where:

$i$  = past time periods (months for VIP items and quarters for non-VIP items)

$t$  = the current time period

ALPHA = the alpha factor (0.05 for VIP items and 0.15 for non-VIP items).

The influence (or weight) of the deviation in any particular time period,  $i$ , depends on how close that period is to the present time,  $t$ :

$$\text{WEIGHT}(i) = \text{ALPHA} \times (1 - \text{ALPHA})^{(t-i)}. \quad [\text{Eq. 5-2}]$$

For VIP items, Table 5-5 displays the weights associated with data from different periods. Data that are 1 year old determine 46 percent of the MAD value. Data that are 2 years old determine 25 percent of the MAD value. Data that are 3 to 8 years old determine the remaining 29 percent of the MAD value.

TABLE 5-5  
MAD COMPOSITION: PERCENT WEIGHTING  
AND AGE OF DATA

Age of data (years)	VIP items (%)	
	Alpha = 0.05	Corrective Alpha = 0.10
1	46	72
2	25	20
3	13	5
5-8	16	3

MAD may not be keeping pace with current forecasting trends because a significant part of its value (29 percent) is determined by forecasts that may be very

different from current forecasts. The problem is exacerbated when forecasts are trending down. The magnitude of the absolute deviation for old, large forecasts will be greater than that of more recent deviations even though relative deviations [Deviation (i) divided by the AMF (i)] may be similar. Thus, large deviations from the past may be making current MADs too big.

A way to make MAD a more accurate estimator of current forecast error is to use corrective alpha values (assigned to C&T items) to calculate MAD. Table 5-5 displays C&T corrective alphas. The corrective alpha is twice as large as the regular alpha and gives greater weight to more recent data. With the corrective alpha, the most recent data (aged 2 years or less) define virtually all (92 percent) of the MAD value.

### ***Simulation Results Versus Historical Data***

The final validation step for forecasts and demands is to compare simulation AMF-to-AMD ratios with historical ratios at the NSN level. Table 5-6 displays three different AMF-to-AMD ratios expressed as a percent: the first from a Flash Report for the first quarter in 1988, the second from a Flash Report in 1986, and the last from the simulation. The two Flash Report ratios, although not identical, are strongly correlated (a sample correlation coefficient of 0.975). The simulation ratios in Table 5-6 were obtained after adjusting the demand knob so that at the PGC level, the simulation matched the PGC ratios from the Flash Reports. Even with that adjustment, simulation ratios at the NSN level are not well correlated with Flash Report ratios. Even when MADs are calculated with corrective alphas, eliminating the simulation's tendency to underforecast, forecast-to-demand ratios at the NSN level may still not correlate well with historical ratios.

The problem is that MAD in the DLA system is designed for QFD items and is not well-suited as an estimator of demand variance for POI items. For pure QFD items, historical data are the basis for forecasts and over- or underforecast tendencies are naturally corrected. For POI items, forecasts are not linked to historical demand and no natural mechanism for corrective action occurs. To obtain better NSN-level realism in the simulation would require the use of additional data, supplementing MAD, that provided insight on NSN-level forecasting tendencies by NSN.

**TABLE 5-6**  
**FORECAST -TO-DEMAND RATIOS**  
**[Woman's shirt PGC (percent)]**

NSN	% AMF/AMD		
	Flash 1988	Flash 86120	Simulation
1	204	131	84
2	201	132	79
3	190	127	67
4	107	113	118
5	140	117	88
6	162	117	78
7	108	110	124
8	127	116	102
9	132	113	91
10	105	111	125
11	119	114	107
12	121	113	90
13	107	110	123
14	109	114	125
15	110	112	106
16	106	109	115
17	112	117	123
18	115	111	108
19	132	140	109
20	112	119	117
21	563	270	112
PGC	115	115	114

The simulation could be modified in three different ways to compensate for over- or underforecasting tendencies at the NSN level. The first way would be to use Flash Report AMF-to-AMD ratios for several years. From those ratios, an NSN-specific empirical distribution could be constructed and used in the simulation. Flash Report data are the most complete, but additional programs would be required to automate the transfer of the Flash Report data to the simulation. However, if Flash Report data from one year to the next are correlated, as the initial analysis suggests, they might not have to be transferred very often.

Another possible way to incorporate NSN-specific forecasting trends into the simulation would be to use the algebraic sum of forecast error (ASFE) data element from the SSCF input file. The sign and magnitude of the ASFE determine the amount of under- or overforecasting that occurs on average. The ASFE is available to the simulation in the SSCF file and would not require additional transfer programs. However, the ASFE procedures in SAMMS should be changed so that ASFE is set to zero more frequently. If not, like the MAD, it may be biased by old data.

The final possibility would be to use SSCF historical demand data and the current forecast to obtain a simple approximation of whether under- or overforecasting is occurring at the NSN level. Again, this information is readily available to the simulation. However, demand data are only for 1 year (4 quarters), the forecast data are for only 1 quarter, and demands and forecast apply to slightly different time periods.

### **Inventory Level Validation**

We now turn to the simulation's ability to match real-world inventory levels. C&T simulation results are basically estimates of average inventory levels over time. This section compares inventory levels from the simulation with historical C&T levels. We first examine on-hand inventory levels, then on-order inventory as a proportion of total inventory, and finally requisition backorders.

Data on the on-hand inventory considered come from the 1988 Flash Report. Table 5-7 displays 1988 peacetime on-hand inventory (expressed in months of forecasted demand) for the woman's shirt PGC. Almost half the NSNs in that PGC have on-hand stock values of 40 months or more. Those values are surprisingly large considering most of the NSNs have peacetime acquisition objectives of 26 months. The NSNs with the large on-hand inventory are the NSNs with high 1986-to-1988 AMF ratios. What has happened is that in 1986, when the order was placed for what was to become on-hand stock in 1988, the AMF was much larger than it was when the order was actually received a leadtime later. The average on-hand stock at the PGC level is 13.5 months in the 1988 Flash Report. In the 1986 Flash Report, the average on-hand stock for the PGC is only 6.9 months, a value closer to the simulation estimate of 6.3 months. Thus, we conclude that the simulation estimates

for on-hand stock will be relatively close to actual on-hand stock averages as long as strong trends are not present in the forecasts.

TABLE 5-7

ON-HAND PEACETIME OPERATING STOCK

[Woman's shirt PGC in months (units/AMF)]

NSN	Flash Report for 1988					Flash % 1986/1988 AMF
	88152	88121	88091	88060	88031	
1	48	49	49	49	50	302
2	42	43	43	46	46	324
3	48	49	49	50	48	468
4	7	7	6	8	8	88
5	47	48	47	48	49	337
6	51	52	52	52	53	464
7	7	7	7	7	7	93
8	45	46	45	45	46	242
9	43	44	44	44	45	267
10	8	8	8	7	7	69
11	31	29	24	26	27	214
12	46	47	46	45	46	260
13	8	8	6	8	8	107
14	7	2	2	2	3	71
15	44	45	42	40	41	235
16	0	0	0	0	0	48
17	0	0	0	0	2	56
18	29	29	24	24	24	219
19	0	0	1	0	0	47
20	2	2	2	2	2	59
21	5	5	4	5	4	66
PGC	518	520	501	508	516	131

We next consider on-order percentages: the ratio of on-order stocks to the sum of on-order and on-hand stocks. The percentage measure allows us to simultaneously consider both on-hand and on-order inventory. We compare the on-order percentage from the simulation with that in the 1988 Flash Reports for all three PGCs in Table 5-8. The simulation results are relatively close to the historical data in the 1988 Flash Reports with the exception of the woman's shirt PGC. The



large on-hand values for that PGC, already discussed, explain why the Flash Report on-order percentages are low. (In 1986, the on-order percentage for the woman's shirt PGC was 73 percent, as opposed to 27 percent in 1988.)

TABLE 5-8

PGC ON-ORDER PERCENT:  
SIMULATION VERSUS HISTORICAL DATA  
[On order/(on order + on hand)]

PGC	Simulation (%)	Flash Report (%) 1988
Woman's shirt	62	27
Men's and women's gloves	49	35
Man's coat	61	85

A key driver of on-order stock levels is the actual leadtime for the PGC. However, historical data on actual leadtime delays are very limited; no MAD is available for leadtimes, for example. The only information available is Control Line Item Number (CLIN) Delinquency Report information, and it is neither NSN- or PGC-specific, but applies across *all* C&T PGCs. To compensate for the lack of historical data, the simulation provides a PLT control knob for increasing or decreasing leadtime delays. For items such as coats, where the simulation on-order percentage is less than the Flash Report percentage, the average delay for coats is likely to be greater than the overall average delay of 55 days shown in the CLIN data. (Coats, in particular, have been a troublesome item for the C&T Directorate in 1988.) To reflect that situation, the user can increase the PLT by moving the PLT knob to a value greater than 1. On the other hand, for men's and women's gloves, the user can decrease the PLT to reduce the simulation on-order percentage.

We turn finally to backorders and supply availabilities. Backorders are the most difficult to validate because of their relative scarcity, at least for POI items. Definitive backorder validation is difficult without more extensive historical data.

Historical backorder estimates are drawn from 14 months of C&T Never-Out Item Reports, which give a snapshot of the backorder status at the end of the month.

No average quarterly or annual values are available. Table 5-9 compares the requisition backorders from the simulation with the historical Never-Out Item Report data for the three PGCs. In Table 5-9, the demand knob for the simulation has been adjusted to match the historical AMF-to-AMD ratios, but no adjustment of the PLT knob has been made. Table 5-9 demonstrates that simulation values are close for gloves, high for shirts, and low for coats. The differences exist for a number of reasons. Simulation backorder estimates for the woman's shirt PGC are probably too high because of the overestimation of MAD. Men's coat backorders may be too low because PLT delays may be too low (suggested by the on-order percentage in the simulation being less than the historical percentage).

In general, Table 5-9 demonstrates that simulation results are the same order of magnitude as historical values. However, until more detailed data are available, the user may have to calibrate the simulation in order to closely duplicate real-world results.

**TABLE 5-9**  
**REQUISITION BACKORDERS AND SUPPLY AVAILABILITIES**

PGC	95% confidence intervals for requisition backorders (units)		Requisition supply availabilities (%)	
	Simulation	Average 1986/1988 Never-Out Item Report	Simulation	Average 1986/1987 Never-Out Item Report
Woman's shirt	100 ± 17	21 ± 10	90.3	96.4
Men's and women's gloves	34 ± 7	31 ± 24	97.9	94.3
Man's coat	23 ± 9	128 ± 112	99.1	95.1

## CONCLUSIONS

In this chapter, we have covered a variety of verification and validation results. In general, the verification results demonstrate that the model is capturing data correctly, following SAMMS procedures for determining levels correctly, and producing results that reflect the basic structure of the C&T inventory process. At

the PGC level, model results agree reasonably well with historical values, after adjusting for significant trends and variability in the historical data.

The greatest strength and the most likely application of the model is to draw conclusions from separate passes: a baseline pass with no policy change and a test pass with a policy change. Model biases would be similar and should not influence the "delta" arising from the policy. The effect of policy changes can be estimated, therefore, even if model results do not replicate real-world performance.

The weaknesses of the model are its inability to estimate the effects of trends and to identify differences at the NSN level. We have suggested modifications to overcome those weaknesses if DLA desires to analyze trends or NSN levels.

Input data are important for any model. More data analysis could and should be done, and the collection of historical data should be improved. An easy improvement would be to use the corrective alpha for POI items so that the MAD for those items keeps pace with changing forecasts. Another improvement would be to develop and collect PGC- or NSN-level estimates on leadtime delay and variability. A third improvement would be to collect and estimate average backorders on an annual or quarterly basis. However, the most important improvement would be to combine Flash Reports and Never-Out Item Reports into a single computerized data base, preferably PC-based. By combining stock levels with backorder estimates, a more complete inventory picture could be obtained. With a computerized data base (as opposed to the present hard-copy medium), essential data analyses could be performed and results quickly incorporated into the simulation.

## CHAPTER 6

### OPERATING INSTRUCTIONS

#### INTRODUCTION

This chapter steps through the process of running the C&T simulation. It starts with the log-on procedure, displays and explains the queries used to configure the model, and describes how to manipulate input and output files. In it, we discuss the SIMSCRIPT commands for transferring sections of input and output files to a spreadsheet program (LOTUS 1-2-3).

The interactive queries that begin a model run can be submitted in minutes. They allow a user to change model inputs and configure the model for different applications. The exhibits in this chapter display the step-by-step responses required to run the simulation as they actually appear on a monitor screen. The underlined responses must be entered through the keyboard. An "[R]" signifies pressing the Return or Enter key.

#### LOGGING ON TO SIMSCRIPT

After turning the PC and monitor on, perform the following:

```
C:>CD\SIM [R]  
C:>\SIM>SIMLAB [R]  
SIMLAB>SELECT DLA [R]
```

EXHIBIT 6-1. LOGGING ON TO SIMSCRIPT

The first command in Exhibit 6-1 changes the directory from the root to the SIMSCRIPT directory; the second calls the SIMLAB software of SIMSCRIPT. The final command accesses the C&T simulation system.

[Note: At this point, the user is able to run the C&T simulation by entering: SIMLAB>RUN[R]. If, however, SSCF reports for the NSNs to be simulated have not yet been processed by the capture program, the user should first type SELECT DLADATA and run the capture program (see Appendix C). Also at this point, if VSLs are to be used in the run and have not already been computed, the user can type SELECT VSL to access the VSL model (see Appendix D).]

### INTERACTIVE QUERIES

This section displays and explains each model query.

SIMLAB>RUN [R]

1) ENTER ##### NUMBER 0 TO 5 FOR THE PGC SELECTED TO RUN #####

	NAME	SERVICE	MAX NSN	PGC NUMBER
0 -	DEMO PGC (MAN'S SHIRT)	ARMY	3	1672
1 -	MAN'S COAT	ARMY	65	1765
2 -	WOMAN'S SHIRT	AIR FORCE	21	1671
3 -	WOMAN'S SKIRT	ARMY	80	1748
4 -	MEN'S SHOE	ALL	113	1505
5 -	MEN & WOMEN GLOVES	ALL	17	1834
6 -	WANT TO ENTER AN ALTERNATE PGC NUMBER			

?

#### EXHIBIT 6-2. QUERY 1

The RUN command (Exhibit 6-2) initiates the interactive query session. Query 1 asks the user to select the PGC to be processed. The query lists the "demo PGC" and five other PGCs that the user may choose. The data for those PGCs are already in the system and will be retrieved automatically. If another PGC is desired, the number 6 should be selected and the query shown in Exhibit 6-3 will appear.

1a) ENTER THE PGC NUMBER (NOTE: BOTH THE SSCFSIM.DAT/MOD AND THE  
MPT011.DAT/MOD FILES MUST ALREADY HAVE THIS PGC'S DATA WITHIN

?

EXHIBIT 6-3. QUERY 1a

Query 1a asks for the four- or five-digit number of the PGC to be run. Query 1a allows the simulation to be run on any PGC desired; however, the SSCF input file prepared by the capture program and the MPT011 input file must have been produced and stored in the files named C:\SIM\DLA\SSCFSIM.DAT and C:\SIM\DLA\MPT011.DAT, respectively. (Separate SSCF and MPT011 input files for modified data also are made available. Those files have a "MOD" extension and are discussed in Queries 9 and 10 of Exhibits 6-12 and 6-13.)

2) ENTER 0 FOR DEMAND (CUSTOMER BEHAVIOR) EQUAL TO MONTHLY FORECAST  
1 FOR VARIANCE IN DEMAND BASED ON MAD OF FORECAST  
>0 FOR DEMAND KNOB (e.g., 0.95 DECREASES MEAN DEMAND BY 5%,  
1.05 INCREASES THE MEAN DEMAND 5% IN RELATION TO FORECAST)

?

EXHIBIT 6-4. QUERY 2

Query 2 (Exhibit 6-4) allows the user to control customer behavior in the simulation and isolate its effect on inventory performance. If a "0" is entered, customer demand is equal to the forecasted demand for the month. If the user enters a "1", the demand for the month varies about the monthly forecast. The monthly demand is drawn from a normal distribution with the forecast as mean and the NSN-specific MAD as the standard deviation.

If a real, positive number other than 1 is entered, the forecast for the month is multiplied by that number and the product becomes the mean in the normal distribution from which monthly demand is drawn. Entering a value of 0.95, for example, causes monthly demands to vary about 95 percent of forecasted values, and the actual demand for the entire PGC over the course of the simulation is approximately 95 percent of the forecast. The demand knob allows the user, to control whether the simulation overforecasts or underforecasts demand at the PGC level. Entering a value less than 1 causes the simulation to overforecast demand, while entering a value greater than 1 causes it to underforecast.

3) ENTER 0 FOR CONSTANT PLT (SUPPLIERS BEHAVIOR) EQUALING THE SSCF PLT  
1 FOR VARIANCE IN PLT WITH AVERAGE BEING 2 MONTHS LATE  
>0 FOR PLT SHAPE KNOB (e.g., .5 DECREASES VARIANCE SO AVERAGE  
IS 1 MONTH LATE; 2 INCREASES VARIANCE SO AVERAGE IS  
APPROXIMATELY 4 MONTHS LATE)

?

#### EXHIBIT 6-5. QUERY 3

Query 3 (Exhibit 6-5) allows the user to control supplier behavior in the simulation. If a "0" is entered, all supplier deliveries arrive exactly as scheduled. That is, the simulated PLT will equal the recorded PLT of the item. If a "1" is entered, deliveries may be delayed (i.e., PLTs different than recorded PLTs). (The underlying delay distribution also provides a small probability that deliveries will arrive slightly early.) Delays are based on an empirical distribution that causes deliveries to be approximately 2 months (55 days) late on average. To increase or

decrease the delivery delay, the user may enter a positive value greater than or less than 1. For example, entering a value of .5 would reduce the variability in delays by 50 percent and cause the average delay to decrease from 2 months to 1 month, and entering a value of 2 would increase delay variability by 200 percent and cause the average delay to increase from 2 months to 4 months.

4) ENTER 0 FOR FINAL RESULTS  
1 FOR A SHORT RUN WITH PLOT & DETAIL TRACES  
?

#### EXHIBIT 6-6. QUERY 4

Query 4 (Exhibit 6-6) allows the user to specify a long run for final results or a short run to see how the item behaves. If a "0" is entered, the model is structured to produce final simulation results. This structuring includes the removal of the warm-up period and the reduction of trace information and other model operations that slow processing time. Long runs should be used when the user is satisfied that the model is configured as desired and final numerical results are to be produced.

If a "1" is entered, the model is structured for a shorter run in years but will produce more detailed information. For a short run, the model produces detailed trace information and dynamic graphic plots of net stock over time and does not discount the warm-up period. Short runs should be used to better understand how the PGC behaves and is influenced by different model inputs.



```
5)ENTER ==== SIMULATION LENGTH IN YEARS =====  
?
```

#### EXHIBIT 6-7. QUERY 5

Query 5 (Exhibit 6-7) allows the user to choose the number of years to be simulated. The more years simulated, the more precise model results will be, but processing time (actual clock time) will be longer. The appropriate number of years to enter depends on the number of NSNs in the PGC, the length of time a user is prepared to wait for results, and the level of precision desired. For final results with a long run, the length of time entered should be from 100 to 600 years for most PGCs. For short runs, 3 to 10 years is usually enough for an initial look, but more years may be entered if desired.

```
6)ENTER 0 NOT TO ACCUMULATE RESULTS ACROSS PGCs  
      1 TO DISPLAY RESULTS OF SEVERAL MODEL RUNS WITH THE SAME PGC  
     10 TO DESTROY EXISTING RUNS, & START RUNS WITH THE SAME PGC  
      2 TO ADD RESULTS OF RUNS OF DIFFERENT PGCS TOGETHER  
     20 TO DESTROY EXISTING RUNS, & START RUNS WITH DIFFERENT PGCS  
?
```

#### EXHIBIT 6-8. QUERY 6

Query 6 (Exhibit 6-8) allows the user to aggregate results across separate PGC runs. Aggregate statistics are needed when several different runs on the same PGC are being done or when several different PGCs are being processed in a sequence of

runs to determine how a policy affects system-level performance. Query 6 controls the format of the Aggregate PGC Report file. If a "0" is entered, statistics from the run about to take place are not printed to the Aggregate PGC Report file. To collect statistics for multiple model runs with the same PGC, a "10" should be entered for the first run and "1" for all other runs. To collect statistics for a series of the same run on different PGCs, a "20" should be entered for the first PGC and a "2" for all other PGCs. Entries of "10" or "20" erase existing information in the Aggregate PGC Report file so that a new report can be produced. The difference between entries "1" and "2" is that "2" causes statistics over different PGCs to be summed to a TOTAL line in the Aggregate PGC Report.

Examples: to compare three runs on the same PGC, one with a PLT control knob value of .5, one with the PLT knob value of 1, and one with a PLT knob value of 1.5, the user would enter 10, 1, and 1 in that order for the three model runs. To see what system backorders are for a system of five PGCs running with VSLs, the appropriate entries would be 20, 2, 2, 2, and 2 for the five runs.

6a) ENTER 5 DIGIT RUN ID NUMBER

?

EXHIBIT 6-9. QUERY 6a

Query 6a (Exhibit 6-9) requests an integer no larger than five digits. This number identifies the run when a series of runs are going to be performed on the same PGC. Query 6a is printed whenever the response to Query 6 is "1" or "10." A run ID number is required so that different runs on the same PGC can be distinguished in the Aggregate PGC Report file. If the Query 6 response is "2" or "20," Query 6a does not appear, and the number of each PGC is used to identify individual PGC results in the Aggregate PGC Report.

```
7) ENTER 0 FOR NO FURTHER CHANGE AND RUN
          1 FOR OPTIONAL INPUT DATA FILES (QUERIES 8 TO 12)
?
```

#### EXHIBIT 6-10. QUERY 7

Query 7 (Exhibit 6-10) allows the user to end the query session or move to the additional queries that involve optional data. In general, the first six queries provide enough flexibility to answer a variety of questions for which the optional queries are not needed. If this is the case, a "0" is the appropriate response to Query 7.

If a "1" is entered, several additional queries are posed. These queries require preparation of data files *prior* to the initial RUN command at the beginning of the query session. In particular, to respond to Query 8 on safety level, the user must have run the VSL model and prepared a file of VSLs (see Appendix D). Queries 9, 10, and 11 allow the user to modify any of the inputs in the SSCF, MPT011, or Alternative Assumption Files, respectively. To make such modifications, the user edits a special copy of the input files with identical file names followed by the extension "MOD" rather than "DAT". Queries 9, 10, and 11 direct the simulation to use the edited "MOD" files as input. *Each time before editing the "MOD" files, it is good practice to copy the original SSCF or MPT011 files (with the extension "DAT") to the file that will be modified (with the extension "MOD").* This action ensures that previous modifications in the "MOD" files are not accidentally included in the current run. Commands for editing and copying files are discussed later in this chapter.

```
8)ENTER 1  FOR VARIABLE SAFETY LEVEL  
        0  FOR FIXED SAFETY LEVEL [D]  
?
```

**EXHIBIT 6-11. QUERY 8**

Query 8 (Exhibit -11) allows the user to use either VSLs or the fixed safety levels in the run. If a "1" is entered, the model automatically uses an optional data file, C:\SIM\DLA\VSL.DAT, that contains NSN-specific VSLs. For that option, the user must have previously generated the VSL in months for each NSN in the PGC and stored that data in the VSL file. The VSL model automatically produces the VSL file (see Appendix D); however, the user may enter other safety levels manually into the VSL file for use by the model.

If a "0" is entered in response to Query 8 (the default option), the model uses the fixed safety level values in months for the NSN that appear in the SSCF input file.

```
9)ENTER 1  FOR OPTIONAL SCF INPUT DATA  
        0  FOR STANDARD SCF INPUT DATA [D]  
?
```

**EXHIBIT 6-12. QUERY 9**

Query 9 (Exhibit 6-12) allows the use of modified SSCF input data. To modify the SSCF data, the user must edit a copy of the SSCF input file named C:\SIM\DLA\SSCFSIM.MOD before running the simulation. Modifying the file is

similar to editing files on a PC with a word processor or full-screen editor. Once in the editing mode, the user simply moves the cursor to the desired element in the file and types a replacement value over the existing value. (Instructions for using the SIMSCRIPT editor appear later.) Once the file has been edited and saved, the user runs the model and enters a "1" in response to Query 9. If a "0" is entered, the original (default) SSCF input file (C:\SIMDLA\SSCFSIM.DAT) is used in the simulation.

10) ENTER 1 FOR OPTIONAL MANAGEMENT POLICY TABLE INPUT DATA (MPT011)  
0 FOR STANDARD MANAGEMENT POLICY TABLE INPUT DATA [D]  
?

#### EXHIBIT 6-13. QUERY 10

Query 10 (Exhibit 6-13) allows the use of modified MPT011 input data. To modify the MPT011 data, the user must edit a copy of the MPT011 table named C:\SIMDLA\MPT011.MOD prior to running the simulation. The editing process for the MPT011 file is similar to that for the SSCF file. Once the MPT011.MOD file has been edited and saved, the model can be run and a "1" entered in response to Query 10. If a "0" is entered, the original (default) MPT011 input file (C:\SIMDLA\MPT011.DAT) is used in the simulation.

Query 11 (Exhibit 6-14) allows the the use of modified inputs and assumptions not contained in the SSCF, MPT011, or VSL files. To make such modifications, it is necessary to first modify the file C:\SIMDLA\ASSUMP.MOD. Once that file has been edited and saved, the user can then run the model and enter a "1" in response to Query 11. If a "0" is entered, the standard (default) assumptions are used in the model run.

Query 11 allows the user to modify certain model parameters and controls without having to change SIMSCRIPT code and recompile the model. The options provided by the Alternative Assumption File in its current form are shown in

```

11) ENTER 1  FOR OPTIONAL ASSUMPTION FILE: M1,M2,T, OPTIONS, TRACES
          0  FOR STANDARD ASSUMPTIONS [D]
?

```

EXHIBIT 6-14. QUERY 11

Exhibit A-4 in Appendix A. In the future, the Alternative Assumption File could be expanded to provide additional options. Currently, it contains the M1, M2, and T values that determine the procurement cycle (see Chapter 3), a trace option to turn off the printing of SSCF input data to the trace output file, and an option to shut off requisition-generating procedures in the model.

```

12) ENTER 0  FOR NO GRAPHICS
          1  FOR PGC NET STOCK PLOT AND HISTOGRAM      [D]
          2  FOR FIRST 3 NSNs NET STOCK PLOT          [D - DEMO]
          3  FOR FIRST 3 NSNs NET STOCK PLOT,BO & AVAILABILITY GRAPHS
?

```

EXHIBIT 6-15. QUERY 12

Query 12 (Exhibit 6-15) is used to control model output. It allows the user to choose the type of graphical presentation the model will display. Query 12 appears only if a "0" has been entered in response to Query 4 (FOR A SHORT RUN WITH PLOT & DETAIL TRACES).

If a "0" is entered in response to Query 12, the model does not display the dynamic graphic plots of net stock. If a "1" is entered, a dynamic plot of net stock for the PGC as a whole (i.e., *not* broken out by NSN) is displayed. If a "2" is entered, a

dynamic plot of net stock for each of the first three NSNs in the PGC is displayed. If a "3" is entered, the net stock plot, pie charts for demand and backorders, and supply availability meters for RTC demand are displayed for the first three NSNs in the PGC.

```

=====
----- MODEL OPTION ASSUMPTIONS (true=1 and false=0) -----
1)PGC NUMBER      1672
2)SIMULATED DEMAND KNOB 1.00 (0:FALSE = DEMAND IS FORECAST,else MAD)
3)PLT DAYS DELAYED KNOB 1.00 (0:FALSE= Constant PLT, else variance)
4)SHORT RUN WITH PLOT  1 (0:FALSE=longer run for definitive results)
5)LENGTH OF SIMULATION      0 TOTAL LENGTH OF RUN WITH WARMUP      0
6)  0: 0 DO NOT ADD; 1=runs for same PGC(10 = 1ST PGC in group);
    2=add different PGC info (20 = 1ST PGC in group)
8)VARIABLE SAFETY LEVEL OPTION  0 (0:FALSE= FIXED SAFETY LEVEL)
9)EDITED THE SSCF DATA  0 (0:FALSE= use standard data with no change)
10)EDITED MPT011 TABLE   0 (0:FALSE= use standard data with no change)
11)EDITED ASSUMPTIONS     0 (0:FALSE = standard assumptions, no change)

    === THIS MODEL RUN WILL TAKE      0.   HOURS REAL TIME ON ZENITH===
    ===== MODEL RUN SUBMITTED, TO ABORT HIT CTRL-C =====

```

#### EXHIBIT 6-16. DISPLAY AFTER QUERIES

This concludes the query session at the beginning of a run. Once the query session has ended and the model run has been submitted, the model displays the list of query responses entered (Exhibit 6-16). If the demonstration PGC or one of the sample PGCs (numbers 1 through 5 in Query 1) is being run, the approximate clock time it will take to run the model on a DLA Zenith PC is listed. To stop a run for any reason, the user may strike the "CTRL" and "C" keys, simultaneously. The model can also be stopped during the query session in the same way.

As the model runs, data are automatically printed to the various output files and if requested, plots are automatically displayed on the screen. Once finished, each plot remains on the screen until the user types an integer and a return, [R]. Printed tables also remain on the screen until the model is finished running. For tables, a "?" appears at the bottom of the screen when the model is finished processing. Again, type an integer and a [R] to advance to the next screen. To replay

any past screens one at a time, press the "F8" key and the model will retrieve and display previous screens.

To make a hard copy of any graphic display, press the "ALT" and "F1" keys simultaneously. A hard copy of the graphics can only be made while the graphic is on the screen and before exiting from the run. To make a hard copy of a table, press the "Shift" and "PrtSC" keys simultaneously.



TO EXIT MODEL RUN, ENTER A INTEGER AND [R]  
?

EXHIBIT 6-17. EXITING A RUN

To exit the model (Exhibit 6-17) and return to SIMLAB, enter an integer and [R]. SIMSCRIPT automatically erases all the graphic displays and tables. From SIMLAB, it is possible to view, edit, print, or copy the output from the run, as discussed next.

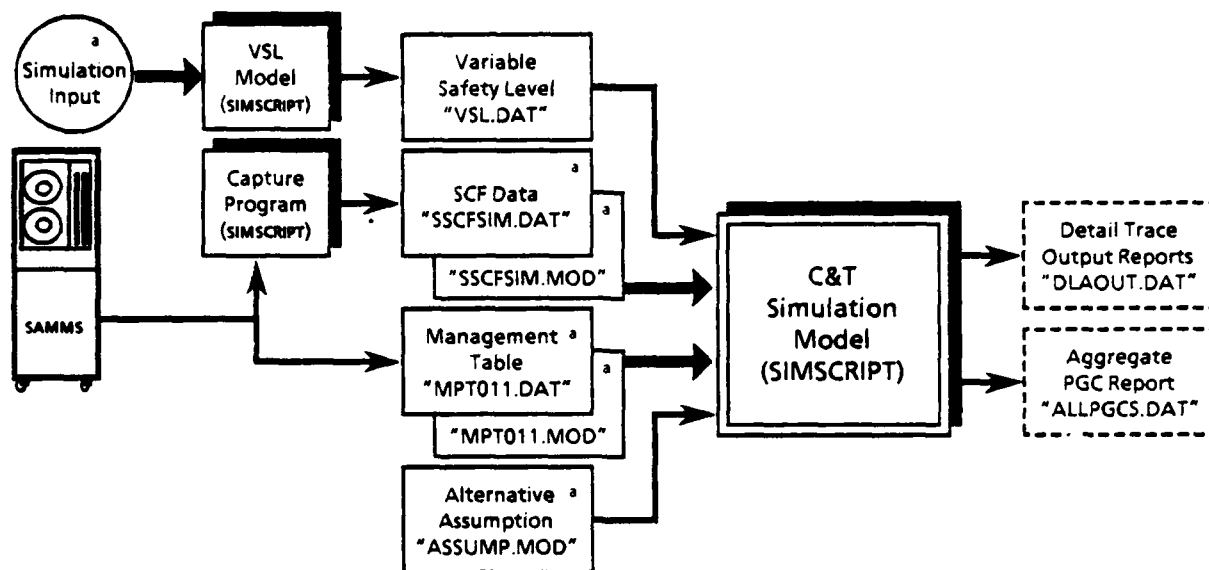
## DATA FILES AND FLOWS

This section summarizes how all the components of the C&T simulation system – the C&T simulation, the capture program, the VSL model, and the various input files and output files in the system – are linked together.

Figure 6-1 illustrates the basic data flows in the system. The hub of the system is the C&T simulation itself. The simulation accepts four types of input files. The two required files are the SSCF input file and the MPT011 file. The "MOD" versions of the SSCF and MPT011 files are used if modified data are desired; otherwise, the "DAT" files with original input data are used. Both inputs are downloaded from the SAMMS data base. The SSCF file is first preprocessed by the SIMSCRIPT capture program (see Appendix C). [Note: The SSCF input data for the demonstration PGC



(#0 in Query 1) is stored in separate files, DEMOPGC.DAT and DEMOPGC.MOD, to avoid the use of regular input files in demonstration and practice with the model.]



<sup>a</sup> These input files to the simulation are also used by the VSL model.

FIG. 6-1. DATA FILES AND FLOWS

The remaining two inputs accepted by the simulation are two optional data files: the Optional Assumption file (see Query 11) and the VSL file (see Query 8). The VSL model generates the VSL file using the same input files as the simulation.

The C&T simulation generates two basic output files: the Aggregate PGC Report (see Query 6) and the Detail Trace Output Report (see Chapter 4).

## FILE MANIPULATION

This section describes the SIMSCRIPT commands that allow a user to view, edit, print, or copy files. SIMSCRIPT contains an editor that can perform most standard editor functions. Any file can be brought into the editor where the user can page through it for viewing, searching for a string, inserting text, and moving blocks of information.<sup>1</sup>

<sup>1</sup>A full description of the SIMSCRIPT editor appears in Chapter 5 of the *PC SIMSCRIPT II.5 Introduction and User's Manual*, Third Edition, published by CACI, Inc., Jul 1987.

### Viewing or Editing a File

To view and edit a file, that file must be brought into the SIMSCRIPT editor. For example, to modify the SSCF input data, the user would type the command shown in Exhibit 6-18.

```
SIMLAB>EDIT/DATA SSCFSIM.MOD [R]
```

EXHIBIT 6-18. ENTERING THE EDITOR

After the above command has been entered, the top of the SSCF input file is displayed on the screen. The user can then move the cursor (using the number pad keys) to the data element to be modified and, making sure the insert mode is off (press the "Ins" key if it is not), enter the new data. New data elements do *not* have to be placed in exactly the same position as old data elements as long as a space is left between adjoining data elements.

```
Esc  
SIMEDIT>EXIT [R]  
SimLab>
```

EXHIBIT 6-19. EXITING THE EDITOR

Once a file has been edited as desired, press the "Esc" key (Exhibit 6-19). The "EXIT" command saves the modified file and exits the editor. A "QUIT" command exits the editor without saving the modified file. Besides modifying the file, the editor can be used to view output as well.

### Printing a File

Hard copies can be printed after viewing the simulation output files. To print a hard copy of the Detail Trace Output Report, enter the command in Exhibit 6-20.



```
SimLab>PRINT/DATA DLAOUT.DAT [R]
```

EXHIBIT 6-20. PRINTING A FILE

By replacing DLAOUT.DAT with the name of any other input or output file, it is possible to print a hard copy of that file too. No file path is required to print the simulation input or output files.

### Copying a File

SIMSCRIPT allows you to make copies of any of the files used. For example, you wish to copy the trace results to an alternate file (because the model rewrites the trace file each time it is run). To perform the "copy" command and any other Disk Operating System (DOS) commands while in SIMSCRIPT, type the desired DOS

command preceded by a "&". For example, the command string in Exhibit 6-21 copies the trace file to a file called SCENARIO.1:

```
SimLab>&COPY C:\SIM\DLA\DLAOUT.DAT C:\SIM\DLA\SCENARIO.1 [R]
```

EXHIBIT 6-21. COPYING A FILE

### Correcting a Run Time Error

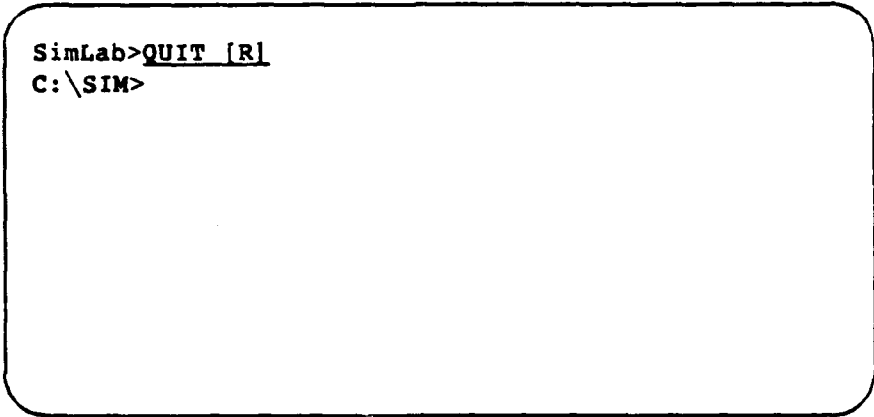
When running the model, a "run time" error may occur. This will happen, for example, if a character is entered when a number is called for. In that case, the debug window will open on the monitor screen and SIMSCRIPT will write an error message. To exit debug and rerun the model, type the commands in Exhibit 6-22.

```
[R]  
Debug>QUIT [R]
```

EXHIBIT 6-22. CORRECTING A RUN TIME ERROR

### Ending a SIMSCRIPT Session

To end a SIMSCRIPT session and return to DOS, enter "QUIT" from the Simlab line (see Exhibit 6-23).



```
SimLab>QUIT [R]  
C:\SIM>
```

EXHIBIT 6-23. ENDING A SIMSCRIPT SESSION

Figure 6-2 summarizes all the SimLab commands discussed in this chapter.

- **TO LOG ONTO SIMSCRIPT**

- C: > CD\SIM [R] *(change to SIM directory from root)*
- C: \SIM > Simlab [R] *(gets to SIMSCRIPT)*
- SimLab > SELECT DLA [R] *(change to C&T model's directory)*
- SimLab >

- **TO RUN THE PROGRAM**

- SimLab > RUN [R]
- 0 [R] (numeric zero) *(moves to next graphic screen)*
- F8 *(flips between screens)*

- **VIEWING OR EDITING A FILE (Example file: DEMOPGC.MOD)**

- To enter, type:  
SimLab > EDIT/DATA DEMOPGC.MOD [R]
- To perform edits or scrolling *(see Chapter 5, PC SIMSCRIPT II.5)*
- To exit, type:
  - Hit ESC key
  - SIMEDIT > EXIT [R] *(saves edits)*
  - SIMEDIT > QUIT [R] *(exits without save)*

- **TO PRINT A FILE**

SimLab > PRINT/DATA DEMOPGC.MOD [R]  
 (Note: To print graphics, press ALT and F1 keys)

- **IN CASE OF ERROR CONDITIONS**

- Write down error message, if past query selection
- [R] *(hit return to get to debug line)*
- Debug > QUIT [R] *(to try again; e.g., if the error is the result of a typo made while entering at keyboard)*

- **TO END SESSION**

SimLab > QUIT

- **TO COPY AND SAVE SIMULATION RESULT IN A SEPARATE FILE (e.g., named "Policy 1") TYPE:**

SimLab > & Copy C:\SIM\DLA\DLAOUT.DAT C:\SIM\DLA\POLICY1 [R]

**Note:** [R] = strike return key; underlining denotes what you enter.

**FIG. 6-2. COMMAND SUMMARY**

## TRANSFERRING FILES TO LOTUS 1-2-3

This section describes how to transfer all or parts of input and output files into LOTUS 1-2-3. LOTUS 1-2-3 allows the user to plot values, calculate additional statistics, and perform other analyses on input or output data. The example in Exhibit 6-24 illustrates how to transfer the Detail Trace Output Report to LOTUS 1-2-3.

```
SimLab><COPY C:\SIM\DLA\DLAOUT.DAT C:\LOTUS\TRANSFER.PRN [R]
```

EXHIBIT 6-24. COPYING TO A LOTUS 1-2-3 FILE

As described earlier, the copy command simply makes a copy of the trace results and stores them in the LOTUS directory under the name of "TRANSFER.PRN". The target file may be assigned any name but does require the "PRN" extension.

```
SimLab><EDIT/DATA C:\LOTUS\TRANSFER.PRN [R]
```

EXHIBIT 6-25. EDITING PRIOR TO LOTUS 1-2-3 OPERATIONS

The command in Exhibit 6-25 calls the just-created copy of the trace report into the SIMSCRIPT editor. The next step is to delete all extraneous data and leave only the data to be manipulated in LOTUS 1-2-3. To delete a character, strike the "DEL" key. To delete lines, strike the "CTRL" and "Y" keys, simultaneously. To delete blocks of information, mark the beginning of the block (type "CTRL" and "K", then "B") and mark the end of the block (type "CTRL" and "K", then "K") and then delete the block (type "CTRL" and "K", then "Y").

Once extraneous information has been deleted, all text headings or titles should be placed between quotes ("TITLE"). Once all editing is finished, the user should save and exit the document ("Esc" followed by "EXIT"). Finally, "QUIT" SimLab.

The "PRN" file just created can now be directly read by LOTUS 1-2-3. The user simply calls the LOTUS 1-2-3 program, selects the "File" command, then the "Import" command, the "Number" command, and finally selects the "TRANSFER" file. The selected data will appear in the spreadsheet.



## CHAPTER 7

### OBSERVATIONS AND SUGGESTIONS

Among the different issues considered in developing the C&T simulation, three require further comment: the implementation of matrix deliveries, the estimation of demand and leadtime variability, and the forecasting of demand. In the course of model development, we recognized that these issues are particularly important in how they influence the simulation and how they influence C&T operations themselves. This chapter offers some observations and suggestions on those issues and presents some ideas for future enhancements to the simulation.

#### MATRIX DELIVERIES

Among the four delivery methods developed for C&T items, Method of Delivery 1 is specifically designed to avoid incremental deliveries. Under Method 1, full order quantities for each NSN in the PGC – whether the NSN is an X, Y, or Z item – are scheduled to be delivered at a single time in the PGC's delivery period. Method 1 is the preferred method of delivery when, for whatever reason, the supplier is better able to deliver whole orders for a given NSN at one time rather than spreading deliveries out over several months. The question is with the way that leadtimes are being defined for items under Method 1.

As described in the DLA documentation available on matrix deliveries [DLAM 4140.2, Chapter 26, *Delivery Schedules* (Working Copy)], some Method 1 items classified as "X" or "Y" will be assigned reorder point leadtime values that do not correspond with the scheduled delivery month for the item. Figure 7-1, which is extracted from DLAM 4140.2, Chapter 26, provides an example.

Following the leadtime-setting rules spelled out in Chapter 26, the leadtime for all "X" items is set to be the time to first delivery plus 2 months. As indicated by the circled entries in Figure 7-1, this results in the last two "X" items being assigned a reorder point leadtime that is 1 month shorter than it should be. That is, if the manufacturer delivers those "X" items exactly on schedule, they will arrive 1 month later than their leadtime says they will arrive. This amounts to "planning" to cut into safety levels for those items and increasing the risk of backorders. (Stochastic

		Months					
		1	2	3	4	5	6
		10%	15%	20%	20%	20%	15%
X		10,000	15,000				25,000
X				20,000			20,000
X					15,000		15,000
X					5,000	7,500	12,500
Y						7,500	7,500
Y						5,000	2,000
Y							6,000
Y							5,500
Z							1,000
Z							500
		10,000	15,000	20,000	20,000	20,000	15,000
							100,000

↑  
1st  
delivery

↑  
X  
PLT

↑  
Y  
PLT

↑  
Z  
PLT

Source: DLAM 4140.2, Chapter 26, *Delivery Schedules* (Working Copy).

FIG. 7-1. METHOD 1 DELIVERY SCHEDULE EXAMPLE

effects will cause variability in the occurrence of backorders from one instance to the next, and safety levels will often cover late deliveries, but even with these qualifications, the leadtime-setting policy as described will cause expected backorder levels to be greater than they would be otherwise.) The same problem exists for the three circled "Y" items.

To avoid the problem of late deliveries, a needs test has been included in C&T matrix delivery planning. The purpose of the needs test is to detect any incursions into safety level caused by the delivery schedule and rearrange the schedule to avoid them. The problem is that this rearrangement usually forces the reintroduction of incremental deliveries, thus defeating the original purpose of the Method 1 approach. When rearrangements are attempted, month-by-month delivery capacities specified in the schedule usually force early deliveries to be spread out in order to make room for the deliveries that have to be moved up. (Figure 7-1 can be

used to see how this happens. To move the delivery of the third X item up, it is necessary to split the delivery of the second X item because the delivery capacity in the third month is 20 percent.)

To avoid this problem for Method 1, an alternative approach would be to set the leadtime for each NSN based on the NSN's scheduled delivery month. This approach would be consistent with the Method 1 goal of avoiding incremental deliveries. It would also reduce the number of times the needs test forces a change in the delivery schedule. The leadtime-setting rules in the new DLAM 4140.2, Chapter 26, *Delivery Schedules* appear to be designed for incremental deliveries. They set leadtimes at reasonable points in the midst of a sequence of partial deliveries. When the full order is delivered at one time, however, it makes sense to simply set the leadtime based on the scheduled delivery month.

The second observation about matrix deliveries concerns the leadtime-setting rules themselves as defined in the new *Delivery Schedules* chapter. The rules work well if the delivery period is 6 months long (i.e., has six delivery increments). They do not work as well if the number of delivery increments is not six. Suppose, for example, the number of delivery increments is 12, corresponding to a 12-month delivery period. Under the rules for Method 4, Z items are assigned a leadtime corresponding to the first delivery time plus five-sixths of the number of delivery increments. On a 12-month schedule, that rule schedules Z items for delivery at the end of the *eleventh* month. [First delivery at the end of month:  $1 + (5/6 \times 12) = 1 + 10 = 11$ .] This does not correspond with the plan to schedule Z items for delivery in the *final* month of the delivery period, as called for under Methods 1, 2, and 4. In some cases, therefore, the leadtime-setting rules, in effect, cause an extra month's worth of stock to be carried — above and beyond the sum of leadtime demand and safety level.

A final observation about matrix deliveries has to do with the needs test. Under DLA's implementation plan, the delivery schedule for a given order of a multi-item PGC is based on the relative mix of actual order quantities among the different NSNs being ordered. Because of the way PGCs are reordered, the actual order quantity for a given item will often be different (smaller) than its full order quantity. (Only when items are at their reorder points is a full order quantity ordered; when items are not at their reorder point, they are ordered only up to their acquisition objective.) This means that items classified as X, Y, or Z based on the

relative size of their *full* order quantity may change class when an actual order is placed. Large order quantity (X) items may account for only a small part of a given order (and therefore become Z items in the delivery schedule), while Z items may be the biggest in the order (and therefore become X items).

This migration of items from one delivery category to another causes planned leadtimes in the delivery schedules to differ from leadtimes used in setting reorder points.<sup>1</sup> Not surprisingly, when the needs test is applied to solve the migration problem, it tends to move problem items back towards delivery points that correspond to reorder point leadtimes (while at the same time, as noted earlier, forcing other, nonproblem items into incremental delivery patterns).

Rather than uncoupling reorder point leadtimes from delivery schedule leadtimes and applying a needs test, an alternative approach would be to always use the same matrix delivery schedule for a PGC based on its full order quantities. X items would always be X items, Y items would always be Y items, and Z items would always be Z items. This alternative would, in effect, couple reorder point leadtimes with delivery leadtimes and remove the need for a needs test.

What DLA gives up if it adopts this "coupled" approach is that occasionally (no more than 20 percent of the time based on preliminary experiments with the simulation) the smaller order quantities in an order may be scheduled for early delivery and the larger quantities for later delivery. This scheduling could theoretically inconvenience suppliers. When this happens, however, the small orders being requested for early delivery will be for the commonly requested sizes. Furthermore, it is not clear that such requests will be that inconvenient for the suppliers. The question is whether supplier delivery preferences are based on the sizes of orders or on the sizes ordered. Suppliers may be quite capable of (and might even prefer) making early deliveries of small orders for commonly requested sizes and later deliveries of larger orders for uncommon sizes.

Finally, a general concern is one of principle. DLA should set a limit on its willingness to "plan" incursions into safety level or backorders to accommodate suppliers. The fundamental reason for developing schedules convenient for

---

<sup>1</sup>We believe the needs test was developed to solve the migration problem. Sensing that delivery schedules based on relative order size might cause some items to be delivered too late, developers of matrix deliveries included the needs test to avoid this happening.

suppliers was that such action would reduce leadtime variability, and *that* would reduce backorders. The needs test cannot, in every case, eliminate all schedule-induced "planned" backorders. By building delivery schedules based on reorder point leadtimes, schedule-induced backorders *can* be avoided altogether, by taking advantage of how reorder point systems work. If other backorders are induced under the coupled approach because of supplier difficulties with delivery schedules, it is not clear that any more backorders are generated than the number of backorders left unresolved by the needs test.

## ESTIMATION OF DEMAND AND LEADTIME VARIABILITY

"Variability of demand" refers to the natural variation in demand from one period (month or quarter) to the next that takes place about the underlying average demand rate. With an average demand rate of 100 units per quarter, for example, a given quarter will usually experience something other than exactly 100 demands; however, from one quarter to the next, demands will distribute themselves about the 100-per-quarter average. Information about the variability of demand is carried by the MAD data element in SAMMS.

As discussed in Chapter 3 (see Equations 3-8 and 3-9) and in Chapter 5, the MAD value for each NSN is a smoothed measure of forecast error. That is, MAD is computed as a weighted average of the difference between actual and forecasted demand in the period just ended (either month or quarter) and the *previous* period's MAD, using an "alpha factor" as a weighting factor. The alpha factor smooths the estimate by combining the forecast error made in the period just ended with the forecast errors of previous periods, recursively embedded in the MAD term.

The concern is that for C&T POI items, current rules for calculating MAD may prevent it from giving as accurate an estimate of demand variability as it could. The suggestion is that DLA should consider using corrective alpha factors in calculating MAD for POI items when POI forecasts have been increasing or decreasing over time.

It is important to calculate MAD properly. As discussed in Chapter 5, MAD plays a key role in the generation of customer demand and significantly influences whether the simulation is able to produce realistic results. If, as suggested in Chapter 5, MAD fails to reflect real-world demand variability as accurately as it

could (because too much weight is being put on "old" forecast errors), the simulation is not as realistic as it could be.

Improving the accuracy of the simulation is not the only reason to change the way MAD is calculated for POI items. The more important reason is that MAD will become very important in determining C&T stockage requirements if and when the C&T Directorate adopts variable safety levels. In the past, with fixed safety levels based on months of demand, demand variability (as measured by MAD) has had no role in the setting of C&T safety levels. It will have such a role if the C&T Directorate adopts VSLs; it serves as the basis for estimating the standard deviation in leadtime demand, which is a key parameter in VSL formulas. (Appendix D presents a complete discussion of how VSLs are computed.)

Separate from demand variability is the question of leadtime variability. Leadtime variability refers to the natural tendency of actual leadtimes to vary around the estimated leadtime, which again is an average. Like demand variability, leadtime variability influences both simulation performance and real-world C&T performance. For the simulation, we have used 6 months of C&T Contract Line Item Number (CLIN) Delinquency Report data to build a probability distribution for the number of days late or early that C&T suppliers deliver replenishment orders. We could, with additional programming, replace that method with NSN-specific leadtime variability distributions if the right data were available.

At C&T operations, variability in leadtime demand is as much a result of leadtime variability as demand variability. And yet, leadtime-demand variability is calculated using only demand variability (as measured by MAD) and the (average) leadtime. No consideration is made of leadtime variability. [For details, see the discussion of mean absolute deviation in leadtime (MADLT) demand in Appendix D.]

We suggest that DLA consider collecting data specifically aimed at getting a better view of leadtime variability at the NSN level. Those data not only would make it possible to improve simulation realism but would be useful in efforts to improve C&T operations. Without good information on leadtime variability at the NSN level, for example, we will be unable to determine whether the new matrix delivery policies are having the desired effect on individual PGCs. (While the CLIN Delinquency reports give good system-wide indications, they do not show results by PGC. The data to be collected under the new matrix delivery procedures is not

focused on leadtime variabilities but rather on how often schedules have to be changed with the needs test.)

If and when the C&T Directorate adopts VSLs, leadtime variability data will be required if it is decided that new safety levels must consider leadtime variability as well as demand variability. Although the consideration of leadtime variability would put the C&T Directorate ahead of other DLA Inventory Control Points, it may be both necessary and appropriate for the C&T Directorate to take that lead, given the nature of C&T suppliers and leadtimes. The mathematics for incorporating leadtime variability into C&T safety levels is not a serious technical problem. (Formulas for including leadtime variability in the calculation of standard deviation in leadtime demand are available in the current literature.)

## DEMAND FORECASTING

Throughout development of the C&T simulation, DLA personnel at both Headquarters and the C&T Directorate have raised the question of improving C&T demand forecasting. The simulation uses Supply Control File data reflecting POI and QFD forecasts to generate new forecasts over time and to generate demands over time. The simulation does not and cannot make C&T demand forecasts any better than they are today.

As fallout from the validation work described in Chapter 5, however, we can suggest a possible approach to the forecasting problem. As part of the validation effort, Flash Reports from 1986 and 1988 were checked for correlations in the data. Any pattern that held in the Flash Reports over time was a possible candidate for comparison with model results for validation. The only category of Flash Report data that showed reasonably high correlation *at the NSN level* (PGC-level correlations were more common) was the ratio of average monthly forecast to average monthly actual demand. In particular, biases in NSN forecasts in 1986 (reflected in forecast-to-actual ratios) usually existed in 1988 in the same direction and to roughly the same degree.

These observations apply only to two PGCs, which account for about 85 NSNs. We cannot conclude, therefore, that forecast biases are stable over time for all C&T items. The fact that the biases did hold for our sample, however, suggests that

possibility. If the stable biases do exist, that information could be used to improve the demand forecasting process at the NSN level.

To test whether NSN-level demand forecasting bias exists, we suggest that DLA undertake a program to accumulate forecast and actual demand data from Flash Reports over time. With easy access to historical Flash Report data, it might be possible to improve the accuracy forecasts. The simulation could also take NSN-level demand bias information into account in its demand-generating processes.

## FUTURE IDEAS AND DIRECTIONS

Like any model, the C&T simulation has areas in which enhancements and improvements can be made. With some additional programming, the following options and features could be added.

A "short-run-with-replications" version of the model could be developed for analyzing trends in demand forecasts and other transient effects. Before taking this step, however, we recommend that DLA consider historical data analysis as an alternative approach to the problem.

An automated batch-processing capability allowing the model to process collections of PGCs automatically, without separate user inputs for each PGC, could be developed. That development would involve the creation of a batch file containing the desired inputs and switch settings to be applied to every PGC in the collection. We suggest that DLA not develop this feature until it decides whether it has to process every PGC in the C&T system in a single run or whether particular subcollections are desirable for different applications. Perhaps by using several PCs, each processing a different collection, DLA can get more flexibility than would be available with a single, total-system batch-processing capability on one machine.

In any simulation, a tradeoff must be made between the level of detail incorporated and the processing time required for a run. The more activities that are simulated, the longer the run. For example, the creation and tracking of requisition demands increases run time by about 30 percent. When total unit demand and overall, unit-level supply performance are the only measures of interest, requisition processing is not needed. An alternative approach to the problem of running time is to use the simulation to help develop and test *analytic* techniques for approximating C&T system effects. Analytic models run considerably faster than simulations, and



an approximate analytic model for C&T inventory management is worth pursuing. Such a model would not attempt to incorporate the exact mathematics to handle multi-item PGCs correctly for every item. Instead, it would produce approximations whose reasonableness could be tested and verified with the simulation.

Finally, models are limited by their data. The better the data, the better the model. More time must be spent comparing real-world results with model results to validate and improve the model. The possibility of incorporating historical Flash Report data to make adjustments to NSN-level demand forecasts, discussed earlier, is an example. Such an effort, however, should be accompanied by an effort to collect more information over longer periods of time and in more usable form. At present, backorder information is only available at the requisition level and represents snapshots taken at the end of each month, without the accumulation of quarterly or annual statistics. The asset information in Flash Reports and the backorder data in Never-Out Item Reports should be combined and made accessible in PC-readable form without having to manually enter data from hard-copy reports.

As DLA Headquarters and the C&T Directorate use the C&T simulation, other desirable features will become apparent. The C&T simulation will also evolve as it is incorporated into larger scale simulation of inventory management across DLA. In this context, the C&T simulation represents a first step towards developing a general-purpose simulation system at DLA that can reflect unique operating practices at each DLA Supply center.

## **APPENDIX A**

### **INPUT DATA**

The five exhibits in this appendix are, respectively, a Standard Automated Materiel Management System (SAMMS) Special Supply Control File (SSCF) report for one national stock number (NSN) (one size of a woman's shirt); the input file for a three-item Procurement Grouping Code (PGC) (man's shirt -- three sizes shown) prepared by the capture program from the SSCF reports for the three NSNs; a Management Policy Table 11 (MPT011) (formatted with new matrix delivery schedule information and with NSN list suppressed); an Alternative Assumption File; and the distribution for determination of requisition sizes.

Together the SSCF input file for the set of NSNs in a PGC and the MPT011 for the PGC contain the required input data for a simulation run on a PGC. Other input information is either control information entered in response to queries or optional information that can be, but does not have to be, supplied prior to a run. Both SSCF and MPT011 files can be modified to contain alternative values through the use of the ".MOD" versions of these files (see the discussion of Queries 9 and 10 in Chapter 6).

\*\*\*\*\*FILE PROCESSED TSV USRMSCTL

TYP NSN I M A C E K M O S U W IND SSC C C CAT IIR IIR  
 REC FSC NIIN P C TOTAL A C E K M O S U W IND SSC C C CAT IIR IIR  
 A 8410 010676705 A 02165 296 010 00914 00000 00000 00000 00945 00000 1 I N BL EA 3 0 R

\*\*\*\*\*FIELD A \*\*\*\*\*FIELD B \*\*\*\*\*LEAD TIMES\*\*\*\*\*

AGE WR PROC D/I STUDY SL ADM PRO REP POST VIP OT PRDC  
 ITEM PLNG CVC REST CODE DVC ICC CD LT LT LT D-DAY IND IND TSCC PCFAC CYCLE ACCI  
 SHIRT, WOMAN'S E N E N Y M P F 229 242 000 000 Y 000 X 012 A

\*\*\*\*\*INHIBIT CODES\*\*\*\*\* \* USER CDS\*\*

SYSTEM C C IIR L DMD STUDY BUY DISP DEMCO SSCS OFD ADM PRO RET SI ANRDP DSSP R F A A T LEVEL SAFE FACTOR IND  
 78308 78308 00000 90047 88047 88017 00000 00000 88031 88017 C C P C P C P O I O O O 001 04.5 1 N

M S MERGER FCST PROC SHELF SHELF STOR PECULIAR MANAGEMENT COST STANDARD PRICE PROV IPE  
 IND. CAIC FAMILY BAS ETC ANRDP GR CD LF MD LF CD MISS CODES B V 5 36 8.15 0.00 0 N

FILL QUANTITIES NEW ITEM RETURNS SAFETY SYSTEM SYSTEM DS MAD ALG SUM PROV PROV  
 NORFOLK OAKLAND QFD 33 278 10.4 9.4 26.4 22.0 00000  
 92 120 4 14

ADDITIONAL MINIMUM INTERMED SHIPPING MINIMUM PGM ROMT PGM ROMT PGM ROMT CONTINGEN OWRMRP  
 RETENTION PROQUIRE PACKAGE CONTAINER CARLOAD 12 MTH ALT/PLT PAST MTH PAST QTR OWRMRP INCR

WS SAFETY \* WS SAFETY \*  
 LEVEL LVL INCR IND

8410 010676705

TYPE TRLR C LOCATION TRAILERS

FPT SMT  
 061 939

EXHIBIT A-1. SPECIAL SUPPLY CONTROL FILE PRINTOUT

\*\*\*\*\*FILE PROCESSED TSV USRMSCTL

TYPE TRLR E		DEMAND / RETURNS		FSC 8410		FAMILY 010676705													
NIIN	SR DM LOC CZ PD CD CD	CURRENT MO	PREV MO	QTY	FREQ	QTY	FREQ	QTY	FREQ	QTY	FREQ	QTY	FREQ	QTY	FREQ	QTY	FREQ	QTY	FREQ
10676705	AO R FFZ 2					1	1												
10676705	AO R FGZ 2					1	1												
10676705	FO N B07 1 P			2	1	2	1												
10676705	FO N B07 2	2	1																
10676705	FO N SAT 1 P					4	2											2	1
10676705	FO R BR4 1 P					7	2	3	1	18	1							4	2
10676705	FO R B07 1 P					2	1											2	1
10676705	FO R FFZ 2 P	2	1					3	2									3	1
10676705	FO R FGZ 2 P	10	1			1	1												
10676705	FO R MAB 1 P					6	2											1	1
10676705	FO R MBB 2 P			3	1	3	1											2	1
10676705	FO R MBB 4 P							2	1										
10676705	FO R SAT 1 P			6	1	6	1	3	1	4	2								
10676705	FO R SAT 3 P							4	1										
10676705	FO R SBT 2 P							1	1										
10676705	FO R SMT 1 P																	4	2
10676705	HO R BR4 1							29	5										
10676705	HO R B07 1					1	1												
10676705	HO R B07 2					1	1	5	2										
10676705	HO R FGZ 2							3	1										
10676705	HO R FHZ 1					3	1												

EXHIBIT A-1. SPECIAL SUPPLY CONTROL FILE PRINTOUT (Continued)

\*\*\*\*\*FILE PROCESSED TSV.USRMSCTL

TYPE	TLR	U	PROGRAM	ORIENTED	ITEM	TRAILER	PIC	PGM	FCST	CD	LAST	FCST	NSN	8410	010676705
------	-----	---	---------	----------	------	---------	-----	-----	------	----	------	------	-----	------	-----------

FOIA ! 01 88

QUANTITIES FIRST FISCAL YEAR

130 JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

1. What is the main purpose of the document?  
 2. What are the key findings of the study?  
 3. What are the limitations of the study?  
 4. What are the implications of the study?  
 5. What are the conclusions of the study?  
 6. What are the recommendations of the study?  
 7. What are the future research directions?  
 8. What are the acknowledgments?  
 9. What are the references?  
 10. What are the appendices?

QUANTITIES SECOND FISCAL YEAR											
OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP

[illegible]

QUANTITIES THIRD FISCAL YEAR

JUL  
JUN  
MAY  
APR  
MAR  
FEB  
JAN  
DEC  
NOV  
OCT

1. *What is the main purpose of the research?*  
 2. *What are the research objectives?*  
 3. *What is the research methodology?*  
 4. *What are the research findings?*  
 5. *What are the conclusions?*  
 6. *What are the limitations of the study?*  
 7. *What are the implications of the study?*  
 8. *What are the future research directions?*  
 9. *What are the contributions of the study?*  
 10. *What are the key words?*  
 11. *What is the abstract?*  
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 213. *What are the results?*  
 214. *What are the conclusions?*  
 215. *What are the limitations?*  
 216. *What are the implications?*  
 217

TYPE INK & PROGRAM ORIENTED ITEM MAILER  
PIC FUM PCS1 CD LAST PCS1  
NSN 8410 0100/0703

5  
1  
FUND

QUANTITIES FIRST FISCAL YEAR												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP

[illegible]

QUANTITIES SECOND FISCAL YEAR

JUL  
AUG  
SEP  
OCT  
NOV  
DEC  
JAN  
FEB  
MAR  
APR  
MAY  
JUN

QUANTITIES THIRD FISCAL YEAR											
OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP

[illegible]

TYPE	TRLR U	PROGRAM ORIENTED	ITEM TRAILER	PIC	PGM FCST CD	LAST FCST	NSN	8410	010676705
------	--------	------------------	--------------	-----	-------------	-----------	-----	------	-----------

FOIPA b 8 01 88

QUANTITIES FIRST FISCAL YEAR

DEC JAN FEB MAR APR MAY JUN JUL AUG SEP

8000000000 8000000000 8000000000 8000000000 8000000000 8000000000 8000000000 8000000000 8000000000 8000000000

[illegible]

000000008 000000008 000000008 000000008 000000008 000000008 000000008

QUANTITIES THIRD FISCAL YEAR

DEC JAN FEB MAR APR MAY JUN JUL AUG SEP

00000006 000000007 000000007 000000007 000000007 000000007 000000007 000000007 000000007

**EXHIBIT A-1. SPECIAL SUPPLY CONTROL FILE PRINTOUT (Continued)**

```

*****NEW      PROCUREMENT GROUPING CODE *****
PROC.GR.CD  1672      MAX.NSN      3
ITEM  NAME      FSC  ICC  ADM.LT  STANDARD.PRICE  MAX.MONTH
SHIRT,MAN'S      8405  P      195      7.25      36
NSN      NIIN      PRO.LT  VIP(1=Y)  FIX.SAFE      QFD
1      010772955      255      1      4.5      6
2      010772957      255      1      4.5      105
3      010772959      255      1      4.5      444

NSN      MAD      OWRMRP  ALPHA      ARS      PER.RTC.DEMAND
1      296.0      0      0.      21.0      .1296
2      2611.0      0      0.      76.0      .4661
3      5166.0      0      0.      94.0      .4185

NSN  1 NIIN 010772955 CT REQUIREMENT MATRIX FOR 36 MONTHS *****
MONTHS:  1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6
        410      380      415      402      417      428
        420      430      431      422      419      411
        410      421      416      404      422      430
        420      432      432      421      407      401
        411      410      406      404      408      418
        422      422      421      424      424      424

NSN  2 NIIN 010772957 CT REQUIREMENT MATRIX FOR 36 MONTHS *****
MONTHS:  1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6
        5791      6147      6104      5432      6289      6791
        6375      6948      6979      6424      6233      5843
        5791      6378      6118      5448      6417      6847
        6364      7031      7003      6366      5592      5275
        5861      5807      5564      5461      5704      6263
        6476      6433      6407      6551      6551      6551

NSN  3 NIIN 010772959 CT REQUIREMENT MATRIX FOR 36 MONTHS *****
MONTHS:  1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6
        13365      13923      14009      12626      14389      15419
        14564      15742      15808      14668      14277      13474
        13365      14515      14041      12660      14653      15539
        14544      15912      15856      14548      12958      12304
        13509      13401      12899      12687      13185      14335
        14772      14681      14630      14927      14927      14927

END.OP.PGC  1672      PGC QRQMT      000 PGC QD      000 %A/R  0
*****

```

EXHIBIT A-2. SSCF INPUT FILE



```

#####
#####  ALTERNATIVE ASSUMPTION FILE  #####
#####

```

```

*****  PROCUREMENT CYCLE DATA  *****

```

```

T      M1      M2
365    925    9999

```

```

*****  OVERRIDE TRACES AND OPTIONS  *****

```

TRACES AND OPTIONS: 1 = TRUE and 0 = FALSE

0 TRACE17: if 1 (TRUE) will print the values read in from the  
SSCF file to the output file, DLAOUT.DAT , if 0 will not.

0 DO REQUISITION OPTION: if 1 will have requisition and recruit info.  
generated, if 0 will treat daily demand as the requisition size

EXHIBIT A-4. ALTERNATIVE ASSUMPTION FILE

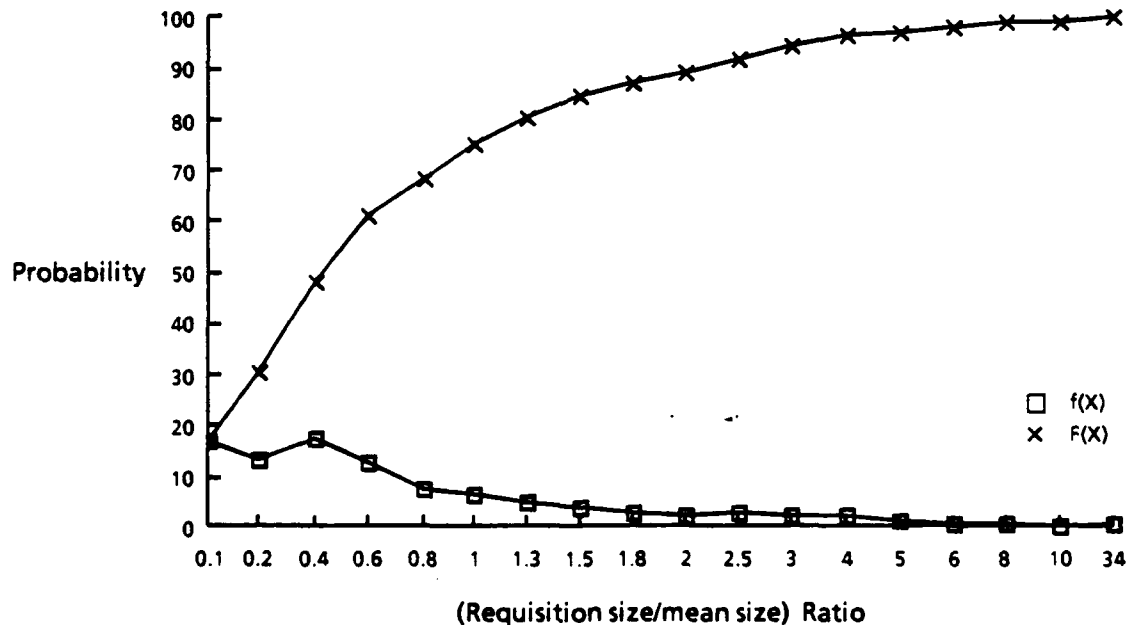


EXHIBIT A-5. REQUISITION SIZE RATIO DISTRIBUTION



## APPENDIX B

### OUTPUT DATA

#### AGGREGATE PROCUREMENT GROUPING CODE (PGC) REPORT

===== AGGREGATE PGC REPORT =====  
3 PGC RESULTS IN SUMMARY (FILE ALLPGCS.DAT)

PGC /ID	-----AVERAGE--		--%REQT--		-----STOCK LEVELS-----			-----DEMAND-----		
	BOH	SUP AVAIL			(\$ 1,000,000 )			UNIT	REQT	RTC REQT
	UNIT	REQT	ALL	RTC	ONHAND	ONORDER	SAFETY	AMD/100	AMD	AMD
1834	1853	106	96	97	88	132	54	740	1220	38
1765	282	38	99	98	119	189	69	224	1864	96
1672	751	11	97	97	10	25	7	211	257	15
TOTAL	2886	155	98	98	217	346	130	1175	3341	149

KEY: AMD = AVERAGE MONTHLY DEMAND  
 REQT = REQUISITIONS  
 ALL = ALL CUSTOMERS (PICS)  
 RTC = RECRUIT TRAINING CENTERS  
 BOH = BACKORDERS ON HAND  
 SUP AVAIL = SUPPLY AVAILABILITY

#### LONG-DURATION TRACE OUTPUT

===== THE DETAIL TRACE OUTPUT REPORT =====  
 ===== (FILE: DLAAUT.DAT) =====  
 (ID NUMBER OF RUN 0)

===== INPUT DATA =====

----- MANAGEMENT POLICY TABLE 11 FILE INPUT -----  
 PGC 1672 METHOD OF DELIVERY 4 PGC FIRST DELIVERY DAYS 165  
 X = 5% Z = 1% MINIMUM PROC CYCLE 6

MONTH =	1	DELIVERY.PERCENT	15
MONTH =	2	DELIVERY.PERCENT	15
MONTH =	3	DELIVERY.PERCENT	20
MONTH =	4	DELIVERY.PERCENT	20
MONTH =	5	DELIVERY.PERCENT	15
MONTH =	6	DELIVERY.PERCENT	15

\*\*\*\*\*  
 \*\*\*\*\* PGC SPECIAL SUPPLY CONTROL FILE INPUT DATA \*\*\*\*\*

PROC.GR.CD 1672 NUMBER OF NSN 3

ITEM	NAME	FSC	ICC	ADM.LT	STANDARD.PRICE	MAX.MONTH
	SHIRT,MAN'S	8405	P	195	7.25	36
NSN	NIIN	PRO.LT	VIP(1=Y)		FIX.SAFE	QFD
1	010772955	255	1		4.5	6
2	010772957	255	1		4.5	105
3	010772959	255	1		4.5	444

NSN	MAD	OWMRP	ALPHA	ARS	PER.RTC.DEMAND
1	296.0	0	0.	21.0	.1296
2	2611.0	0	0.	76.0	.4661
3	5166.0	0	0.	94.0	.4185

\*\*\*\*\*  
 \*\*\*\*\* SIMULATION DATA DESCRIPTION \*\*\*\*\*  
 \*\*\*\*\*

DELIVERY MATRIX FOR X, Y, AND Z ITEMS

XYZ	1	2	3	4	5	6	!	SUM%
1	.150	.150	.200	.200	.150	.150	!	96.41
2	.150	.150	.200	.200	.150	.150	!	3.59
3	0.	0.	0.	0.	0.	+1.E+014	!	.00

SUMMARY OF MONTHLY TOTAL FORECAST AND C&T 36 MONTH POI FORECASTS

NSN	TOTAL AMF	POI AMF	POI STD	% POI STD/POI AMF
1	419	417	10.7	3
2	6247	6212	482.0	8
3	14371	14223	991.0	7

\*\*\*\*\*  
 \*\*\*\*\* MODEL OPTION ASSUMPTIONS (true=1 and false=0) \*\*\*\*\*  
 1)PGC NUMBER 1672  
 2)SIMULATED DEMAND KNOB 1.00 (0:FALSE = DEMAND IS FORECAST,else MAD)  
 3)PLT DAYS DELAYED KNOB 1.00 (0:FALSE= Constant PLT, else variance)  
 4)SHORT RUN WITH PLOT 0 (0:FALSE=longer run for definitive results)  
 5)LENTH OF SIMULATION 100 TOTAL LENGTH OF RUN WITH WARMUP 105  
 6) 2: 0 DO NOT ADD; 1=runs for same PGC(10 = 1ST PGC in group);  
 2=add different PGC info (20 = 1ST PGC in group)  
 8)VARIABLE SAFETY LEVEL OPTION 0 (0:FALSE= FIXED SAFETY LEVEL)  
 9)EDITED THE SSCF DATA 0 (0:FALSE= use standard data with no change)  
 10)EDITED MPT011 TABLE 0 (0:FALSE= use standard data with no change)  
 11)EDITED ASSUMPTIONS 0 (0:FALSE = standard assumptions, no change)  
 o DAILY DEMAND RATE FROM POISSON DIST. 0 (0:FALSE=MONTHLY DEMAND/30)  
 o REQUISITION GROUPINGS FOR DEMANDS 1 (0:FALSE=REQ.SIZE=DDR each day)  
 o SIMULATED DEMAND via MAPE 0 (0:FALSE =NO adjustments used)  
 o NORMAL CTREQ DISTRIBUTION 1 (0:FALSE= 1ST 3yrs. are actual CTREQ)  
 o COVARIANCE FOR ALL NSNs 0 (0:FALSE= only PGC covar calculated)

ALT 195	PLT OF FIRST DELIVERY	165	COST \$	7.25
---------	-----------------------	-----	---------	------

	M1	925.0	M2	9999.0	T	365						
NSN	RTC	CUT	ARS	%RTC	STOCK	OWRM	PLT	SAFETY	MTHS	%SD/AMF	VIP	XYZ
1	342		21	13	8107	0	255.0	4.500		88.4	1	2
2	200		76	47	120199	0	255.0	4.500		52.2	1	1
3	293		94	42	276413	0	255.0	4.500		44.9	1	1

```

===== THE SIMULATION OVER TIME =====

```

[illegible]

BEGINNING OF MONTH				1 C & T LEVELS & DEMANDS BY NSN (time.v 1800)					
NSN	30xDDR	FORCTS	PCP.MTH	MIN.PC	ROP QTY	STOCK	ORDER	UBO	RBO
1	656	417	11.0	6.0	8238	6639	3938	0	0
2	7695	6020	6.0	6.0	118268	54468	88867	0	0
3	12503	13780	6.0	6.0	290497	106432	239339	0	0
QUICK NSN	1 YR	16.0 MEAN	1	NETSTOCK	17877	CI	1	%CI/AVE	168
QUICK NSN	1 YR	18.0 MEAN	0	NETSTOCK	139379	CI	1	%CI/AVE	171
QUICK NSN	1 YR	20.0 MEAN	0	NETSTOCK	155878	CI	1	%CI/AVE	174
QUICK NSN	1 YR	22.0 MEAN	0	NETSTOCK	110991	CI	1	%CI/AVE	176
QUICK NSN	1 YR	24.0 MEAN	2	NETSTOCK	141788	CI	2	%CI/AVE	137
QUICK NSN	1 YR	26.0 MEAN	2	NETSTOCK	179107	CI	2	%CI/AVE	139
QUICK NSN	1 YR	28.0 MEAN	1	NETSTOCK	200079	CI	2	%CI/AVE	140
QUICK NSN	1 YR	30.0 MEAN	1	NETSTOCK	178413	CI	2	%CI/AVE	141
QUICK NSN	1 YR	32.0 MEAN	1	NETSTOCK	144105	CI	2	%CI/AVE	143
QUICK NSN	1 YR	34.0 MEAN	7	NETSTOCK	-31023	CI	10	%CI/AVE	149
QUICK NSN	1 YR	36.0 MEAN	7	NETSTOCK	173541	CI	10	%CI/AVE	150
QUICK NSN	1 YR	38.0 MEAN	6	NETSTOCK	64575	CI	9	%CI/AVE	151
QUICK NSN	1 YR	40.0 MEAN	6	NETSTOCK	146930	CI	9	%CI/AVE	151
QUICK NSN	1 YR	42.0 MEAN	20	NETSTOCK	128760	CI	20	%CI/AVE	100
QUICK NSN	1 YR	44.0 MEAN	19	NETSTOCK	192819	CI	25	%CI/AVE	134
QUICK NSN	1 YR	46.0 MEAN	22	NETSTOCK	-8975	CI	24	%CI/AVE	110
QUICK NSN	1 YR	48.0 MEAN	22	NETSTOCK	84369	CI	23	%CI/AVE	105

END OF MONTH DATA:					MONTH 600	YEAR 50.0 (time.v 1980)				
=CUMMULATIVE=		=AMF=	RATIO	====AVE UNITS=====			==AVE MONTHS==			
NSN	ARS.SM	INTRVL	FORCST	FOR/DD	ONORDER	ONHAND	%O/O	OR/F	OH/F	WAR
1	22.3	1.5	419	90.71	7591	3599	67.8	18	9	0.
2	75.8	.4	6256	101.79	100647	43418	69.9	16	7	0.
3	92.8	.2	14402	96.46	245858	82358	74.9	17	6	0.
=====REQUISITIONS=====					=====UNIT DEMANDS=====					
---AVBOD---			---DEM/YR---		---AVBOD---			---DEM/YR---		
NSN	TOT	RTC	TOT	RTC	TOT	RTC	TOT	RTC	TOT	RTC
1	66.2	68.1	248.1	1.7	68.6	69.4	5538	888		
2	77.7	69.9	973.6	70.7	74.4	65.7	73758	33955		
3	22.8	22.6	1930.2	106.3	23.0	22.6	179164	73053		

-----REQUISITIONS-----					-----UNIT DEMANDS-----			
-----EBOs-----			--FILL RATES--		---EBOs---		--FILL RATES--	
NSN	TOT	RTC	TOT	RTC	TOT	RTC	TOT	RTC
1	2.8	.04	93.8	88.10	64.9	17.13	93.9	89.99
2	10.7	.59	94.9	95.73	674.2	227.62	95.6	96.32
3	7.3	.42	94.0	93.68	700.2	287.05	93.9	93.75
QUICK NSN	1 YR	50.0	MEAN	22 NETSTOCK	117664	CI	23 %CI/AVE	103

BEGINNING OF MONTH 601 C & T LEVELS & DEMANDS BY NSN (time.v19800)

NSN	30xDDR	FORCTS	PCP.MTH	MIN.PC	ROP QTY	STOCK	ORDER	UBO	RBO
1	331	419	11.0	6.0	8120	4182	6134	0	0
2	6411	6043	6.0	6.0	124692	0	150004	1449	30
3	7085	14393	6.0	6.0	279536	114931	218251	0	0
QUICK NSN	1 YR	52.0	MEAN	21 NETSTOCK	128688	CI	22 %CI/AVE	104	
QUICK NSN	1 YR	54.0	MEAN	21 NETSTOCK	155547	CI	21 %CI/AVE	104	
QUICK NSN	1 YR	56.0	MEAN	20 NETSTOCK	116591	CI	21 %CI/AVE	105	
QUICK NSN	1 YR	58.0	MEAN	19 NETSTOCK	95937	CI	20 %CI/AVE	105	
QUICK NSN	1 YR	60.0	MEAN	18 NETSTOCK	158045	CI	20 %CI/AVE	106	
QUICK NSN	1 YR	62.0	MEAN	18 NETSTOCK	160034	CI	19 %CI/AVE	106	
QUICK NSN	1 YR	64.0	MEAN	17 NETSTOCK	206881	CI	18 %CI/AVE	107	
QUICK NSN	1 YR	66.0	MEAN	17 NETSTOCK	141583	CI	18 %CI/AVE	107	
QUICK NSN	1 YR	68.0	MEAN	16 NETSTOCK	230821	CI	18 %CI/AVE	107	
QUICK NSN	1 YR	70.0	MEAN	16 NETSTOCK	223361	CI	17 %CI/AVE	108	
QUICK NSN	1 YR	72.0	MEAN	15 NETSTOCK	56696	CI	17 %CI/AVE	108	
QUICK NSN	1 YR	74.0	MEAN	16 NETSTOCK	93476	CI	16 %CI/AVE	104	
QUICK NSN	1 YR	76.0	MEAN	15 NETSTOCK	162234	CI	16 %CI/AVE	104	
QUICK NSN	1 YR	78.0	MEAN	15 NETSTOCK	189017	CI	15 %CI/AVE	104	
QUICK NSN	1 YR	80.0	MEAN	14 NETSTOCK	85966	CI	15 %CI/AVE	104	
QUICK NSN	1 YR	82.0	MEAN	14 NETSTOCK	135080	CI	15 %CI/AVE	105	
QUICK NSN	1 YR	84.0	MEAN	14 NETSTOCK	146384	CI	14 %CI/AVE	105	
QUICK NSN	1 YR	86.0	MEAN	13 NETSTOCK	152325	CI	14 %CI/AVE	105	
QUICK NSN	1 YR	88.0	MEAN	13 NETSTOCK	184939	CI	14 %CI/AVE	105	
QUICK NSN	1 YR	90.0	MEAN	13 NETSTOCK	196828	CI	14 %CI/AVE	106	
QUICK NSN	1 YR	92.0	MEAN	13 NETSTOCK	184640	CI	13 %CI/AVE	104	
QUICK NSN	1 YR	94.0	MEAN	12 NETSTOCK	37787	CI	13 %CI/AVE	104	
QUICK NSN	1 YR	96.0	MEAN	12 NETSTOCK	211727	CI	13 %CI/AVE	105	
QUICK NSN	1 YR	98.0	MEAN	12 NETSTOCK	183423	CI	12 %CI/AVE	105	

END OF MONTH DATA: MONTH 1200 YEAR 100.0 (time.v 37800)

-CUMMULATIVE-		-AMF--	RATIO	----AVE UNITS-----			--AVE MONTHS--			
NSN	ARS.SM	INTRVL	FORCST	FOR/DD	ONORDER	ONHAND	%O/O	OR/F	OH/F	WAR
1	21.9	1.5	419	93.04	7296	3864	65.4	17	9	0.
2	76.0	.4	6246	101.57	99645	43507	69.6	16	7	0.
3	93.6	.2	14347	98.73	234794	92619	71.7	16	6	0.

-----REQUISITIONS-----					-----UNIT DEMANDS-----			
---AVBOD---			---DEM/YR---		---AVBOD---		---DEM/YR---	
NSN	TOT	RTC	TOT	RTC	TOT	RTC	TOT	RTC
1	63.8	68.1	246.3	1.6	66.7	69.4	5400	858
2	61.1	55.1	971.1	71.2	57.4	49.1	73789	34160
3	22.7	22.5	1862.9	104.1	22.9	22.6	174371	72132
-----REQUISITIONS-----					-----UNIT DEMANDS-----			
---EBOs---			--FILL RATES--		---EBOs---		--FILL RATES--	
NSN	TOT	RTC	TOT	RTC	TOT	RTC	TOT	RTC

1	1.4	.02	96.7	93.83	32.8	8.57	96.7	94.82
2	5.8	.32	96.5	97.03	367.6	126.35	96.9	97.29
3	3.7	.21	96.9	96.75	350.3	143.60	96.8	96.83
	NSN	1 LAG	1 COVAR	1440.9	COVAR.SUM	2867.36	CORR	.2547
	NSN	1 LAG	2 COVAR	-101.8	COVAR.SUM	2665.81	CORR	-.0180
	NSN	1 LAG	3 COVAR	-127.8	COVAR.SUM	2414.10	CORR	-.0226
	NSN	1 LAG	4 COVAR	-142.2	COVAR.SUM	2135.33	CORR	-.0251
	NSN	1 LAG	5 COVAR	-139.9	COVAR.SUM	2135.33	CORR	-.0247
	NSN	1 LAG	6 COVAR	-119.4	COVAR.SUM	2135.33	CORR	-.0211
	SUMMARY NSN	1 COVAR/N2	2135.3	VAR	5657.6	MEAN	11.690	

=====

===== END OF RUN: PGC RESULTS =====

=====

=== STATS FOR RUN: M.LAGS 4 INTVL 180 BLOCKS 200 YRS 100.0

NSN	MEAN	VAR	2COVAR/N	MEAN.VAR	C.I.95%	%C.I./MEAN
1	12	5657.6	2135.3	39.0	12	104.66

QUICK NSN 1 YR 100.0 MEAN 12 NETSTOCK 129667 CI 12 %CI/AVE 105

===== SUMMARY PGC REPORT =====

===== (PGC NO. 1672 RUN ID 0) =====

PGC NAME	SHIRT,MAN'S	NSNs	3 COST	7.25 ORDERS/YR	2.24
TIME WGT BO	===== AVAILABILITY ===== DEMANDS/YR ==				
TOT	RTC	TOT	RTC	TOT	RTC
REQUISIT.	10.9	.6	96.75	96.84	3080
UNITS	750.7	278.5	96.85	96.96	253560

AVERAGE:===== STOCK ===== ONORDER ===== SAFETY LEVEL =====

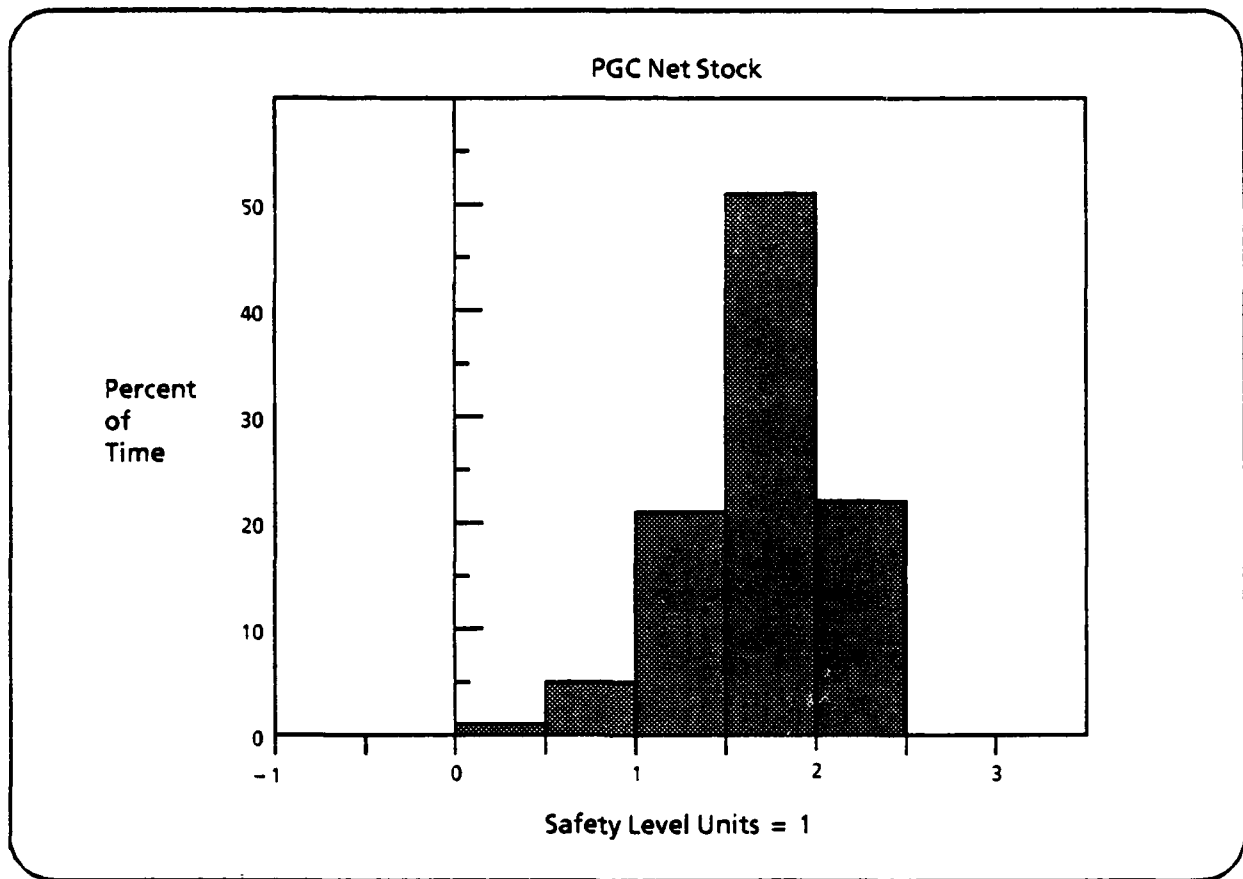
UNITS	139991	341734	94664
DOLLARS	1014932	2477570	686311

===== CALIBRATION/VALIDATION INFORMATION =====

TIME.V(YR) 105.0 SIM (YRS) 100.0 WARMUP 5 (REVIEW 2 DEMAND 1 DAYS)

PGC.BO	%CI/MEAN	AVE NET STOCK	%OR/OH+OR	% FORE/DEMD	YR FORCST
12	104.66	139465	70.94	99.44	252136

PGC	BOH	SUP AVAIL	ONHAND	ONORDER	SAFETY	UNIT	REQT	RTC	REQT
/ID	UNIT	REQT	ALL RTC	(\$ 100,000)		AMD/100	AMD	AMD	
1672	751	11	97 97	10	25	7	211	257	15



**EXHIBIT B-1. PGC NET STOCK HISTOGRAM**

## APPENDIX C

### THE DLA DATA CAPTURE PROGRAM

This appendix describes the steps involved in the clothing and textiles (C&T) simulation system for obtaining Special Supply Control File (SSCF) input data from the Defense Logistics Agency (DLA) Standard Automated Materiel Management System (SAMMS). We discuss the requirement to download this information to a personal computer (PC) and to run the "capture" program, which converts raw SAMMS SSCF data into a smaller SSCF input file for the simulation. The steps described here are necessary before any simulation runs can be performed. They need only be performed once for each Procurement Grouping Code (PGC), and multiple PGCs may be processed at the same time.

The capture program reads a downloaded SAMMS file, extracts the information required by the simulation, and stores it on the PC hard drive. Once this is done, the large SAMMS data file can be deleted to save storage space on the PC. There are three basic steps to perform the capture process.

The first step is to submit a request to SAMMS for SSCF reports to be generated. The request requires that all national stock numbers (NSNs) in the PGC to be simulated are entered and that all NSNs within the PGC have the same PGC number. The user can enter NSNs from as many PGCs as desired, but the request must group NSNs by PGC. The user must also specify that the output medium should be a file on the mainframe, not a hard copy. (SSCF reports are normally produced in SAMMS in hard copy.)

The second step is to download the file of raw SSCF reports from the mainframe to a PC — either to the hard drive (preferable) or to floppy disks. This can be accomplished with a direct telecommunications link between the PC and the mainframe or through the use of an intermediate device (e.g., a minicomputer or tape reader) able to receive a copy of the mainframe file and download it to a PC. Whatever the case, the SAMMS file of SSCF reports must be stored in a file called C:\SIMDLADATA\SSCFTAPE on the PC.

The third and final step is to run the capture program and produce the file C:\SIMDLA\SSCFSIM.DAT for the simulation to use. Results of a current run of the "capture" program will overwrite the contents of this file from previous runs. To save previously captured data, capture output should be copied to an alternative file name. The "capture" program can then be run to create a new SSCF for the next PGC. If desired, captured files for different PGCs can be concatenated to form one SSCFSIM.DAT file, which can contain SSCF data for more than one PGC.

The screens that follow show the step-by-step process (user input underlined) required to run the "capture" program.

```
C:>CD \SIM [R]  
C:>\SIM>SIMLAB [R]  
SimLab>SELECT DLA [R]  
SimLab>RUN
```

EXHIBIT C-1. RUNNING THE CAPTURE PROGRAM

The first command (Exhibit C-1) changes the directory from the root to the SIMSCRIPT directory, the second command calls the SIMLAB software of SIMSCRIPT, the third command accesses the DLADATA capture program, and the final command runs the capture program. Next, the following information will appear on the monitor:



```
=====
THIS PROGRAM CAPTURES THE DATA FROM THE SPECIAL SUPPLY CONTROL
FILE (SSCF) REPORT.  THE SSCF REPORT FILE MUST BE STORED IN:
C:\SIM\DLADATA\SSCFTAPE
FOR THE CAPTURE PROGRAM TO RUN PROPERLY
```

```
THE OUTPUT OF THIS PROGRAM GOES DIRECTLY TO THE SIMULATION
MODEL DIRECTORY, TO BE INCORPORATED AUTOMATICALLY WHEN THE
SIMULATION RUNS.  THAT OUTPUT FILE IS:
C:\SIM\DLA\SSCFSIM.DAT
```

```
----->  IMPORTANT NOTE:  <-----
```

```
RUNNING THIS PROGRAM WILL OVERWRITE THE EXISTING DATA IN THE
SSCFSIM.DAT FILE WITH NEW DATA.  IF YOU HAVE NOT BACKED UP THE
CURRENT CONTENTS OF SSCFSIM.DAT OR WANT TO READ CHAPTER 2 OF
THE DOCUMENTATION FOR FURTHER EXPLANATION
```

```
PRESS:  CTRL-C
(TO STOP THIS CAPTURE PROGRAM )
```

```
=====
```

#### EXHIBIT C-2. CAPTURE FILE MAINTENANCE INFORMATION

The screen in Exhibit C-2 repeats the aspects of the capture process just discussed. Note that the "capture" program can be interrupted and stopped by striking the "CTRL" and "C" keys simultaneously.

## APPENDIX D

### THE C&T VARIABLE SAFETY LEVEL MODEL

#### INTRODUCTION

This appendix describes the Clothing and Textiles (C&T) Variable Safety Level (VSL) model: what the model is, what it does, its output, and the connection between the VSL model and the C&T simulation.

The VSL model is an analytical inventory model. The mathematics in the C&T VSL model is the same as that in the Standard Automated Materiel Management System (SAMMS) for computing VSLs for other Defense Logistics Agency (DLA) commodities. The C&T VSL model allows the use of certain variations in the standard DLA VSL mathematics to accommodate unique C&T characteristics. The model derives the amount of safety stock that each item [national stock number (NSN)] in a collection or system of items should receive in order to minimize the total number of time-weighted backorders in the system for a given investment in safety level. The system of items may be the NSNs in a single, multi-item procurement grouping code (PGC) or the collection of NSNs in a group of different PGCs.

The VSL model is used to supplement the modeling capabilities of the C&T simulation. It produces a mix of safety levels for the system of items it processes. This mix takes many important C&T characteristics into account to compute a "best" mix. The C&T VSL model, however, does *not* take the special, multi-item reordering features of a multi-item PGC into account. The simulation, on the other hand, considers *all* the key features of C&T inventory management, including the multi-item reordering feature. It, however, cannot determine the best safety level mix for the system of items being simulated. The two models together give a more complete picture of C&T safety levels and system backorders. The VSL model computes a safety-level mix, and the simulation estimates the number of backorders generated with that mix. Together, the two models allow DLA to test whether the VSL approach at C&T will lead to better performance than that achieved with fixed safety levels.

At present, the C&T Directorate uses a fixed safety level for most of its NSNs. In the case of "bag items" issued to recruits, for example, fixed safety levels are set by item to be 4.5 months of demand. Fixed safety levels only consider demand, while VSL calculations take other factors into account as well. The simulation can test both types of safety levels to predict which safety level produces better system performance (e.g., fewer backorders).

Since comparing fixed safety levels with VSLs is a key purpose of the C&T simulation system, the VSL model and C&T simulation are closely connected. Both models use the same data bases, the same leadtimes, and the same order quantities. Users can use VSL model results in the simulation (in the form of a file of VSLs) by responding appropriately in the query session at the beginning of a simulation run.

The SIMSCRIPT source code for the VSL model appears in Volume II of this report.

## ASSUMPTIONS AND EQUATIONS

The assumptions and key equations of the VSL model are derived from SAMMS documentation and from a DLA publication, *Review of SAMMS Requirements Computations*, August 1985, M. K. Cyrus et al., p. 40.

The basic SAMMS equations for determining the safety level for NSN (i) are:

$$VSL_i = SD \times k_i \quad (\text{in units}) \quad [\text{Eq. D-1}]$$

$$VSL_i = \frac{SD \times k_i}{AMF} \quad (\text{in months}) \quad [\text{Eq. D-2}]$$

where:

AMF = average monthly forecast,

SD = standard deviation of unit demand during a leadtime, and

$k_i$  = the safety level factor defined by:

$$k_i = -0.7071 \ln \left[ \frac{2.56 S_i Q_i c_i \beta}{ZE_i(MADLT_i) \left( \sum_j c_j MADLT_j \right) \left( 1 - \exp(-1.13 Q_i / MADLT_i) \right)} \right] \quad [\text{Eq. D-3}]$$

where:

- $Q_i$  = order quantity for item (i)
- $MADLT_i$  = mean absolute deviation of leadtime demand for item (i)
- $ZE_i$  = essentiality factor for item (i)
- $S_i$  = average requisition size for item (i)
- $c_i$  = unit price for item (i)
- $\beta$  = on-hand unit backorders for the system (the Beta constraint)
- $\sum_j MADLT_j$  = product of item MADLT and cost, summed over the system of items
- $j$  = the number of NSNs in the system.

To adapt the SAMMS VSL equations to the special characteristics of C&T inventory management, the order quantity (Q), the essentiality factor (ZE), and the average requisition size (S) elements can all be modified.

### The Order Quantity, Q

The C&T Directorate has expressed the concern that SAMMS VSL formulas do not account for incremental deliveries. To adapt the SAMMS VSL formulas for incremental deliveries (which occur naturally under Delivery Methods 2, 3, and 4), we can replace the value for order quantity, Q, with an alternative value derived as follows.

The order quantity, Q, in Equation D-3 may be viewed as a measure of average on-hand stock. In particular, in a standard deterministic system with constant demand and no safety level or backorders,  $Q/2$  equals the average amount of stock on hand. This holds because in a standard system order quantities are delivered in clumps. If order quantities are delivered incrementally, the average amount of stock on hand changes slightly. Figure D-1 illustrates an example.

Figure D-1 illustrates the on-hand stock profiles over time of an NSN with clumped deliveries (dashed line) and incremental deliveries (solid line) under deterministic conditions. The NSN has a procurement cycle period (PCP) of 12 months. Under incremental deliveries, the NSN has six deliveries and the first delivery is 3 months early (ME). (With incremental deliveries, a portion of the order

quantity is delivered early, in effect, because leadtimes fall in the middle of incremental delivery schedules.) Under clumped deliveries, the entire order quantity for the NSN arrives at the end of the leadtime ( $ME = 0$ ). Examination of the figure shows that the average stock on hand under clumped deliveries is 6 months' worth of demand, but is 6.5 months' worth with the incremental delivery. The average on-hand stock for any delivery scheme, whether incremental or not, is given by Equation D-4:

$$\text{Average on - hand stock} = \left( \frac{\text{PCP} - \# \text{ of deliveries} + 1}{2} + ME \right) \times \text{AMF} \quad [\text{Eq. D-4}]$$

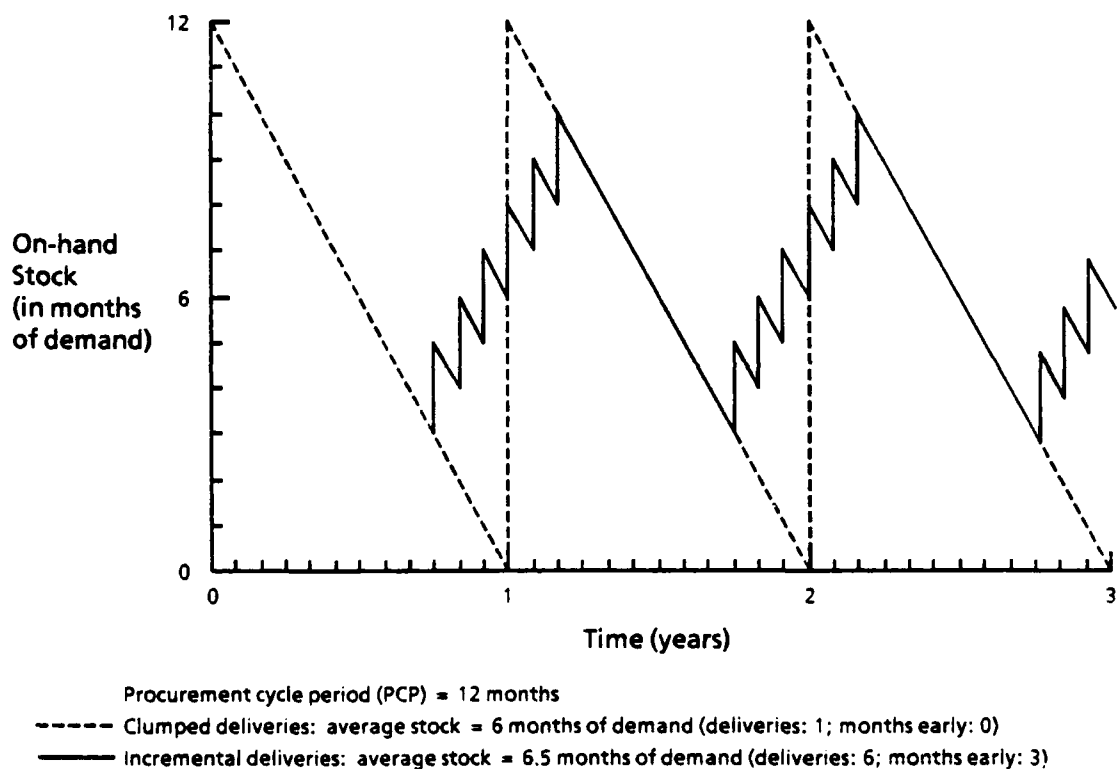


FIG. D-1. ON-HAND STOCK UNDER CLUMPED vs INCREMENTAL DELIVERIES

The values for the number of deliveries and months early depend on which matrix delivery method applies to the PGC and whether individual NSNs are X, Y, or Z items. As an estimation of average stock on hand, the formula given by Equation D-4 works for all four methods of matrix delivery and for all three types of items (X, Y, or Z).

The C&T VSL model allows the user two different options in setting a value for Q in the VSL formula (Equation D-3). Under the incremental delivery option, Q is replaced by the expression in Equation D-4 times two. The second option is to ignore incremental deliveries and to set Q to be the computed procurement cycle quantity.

### Deviation in Demand Leadtime

In SAMMS, the MADLT for an NSN is derived using the following general formula:

$$\text{MADLT}_i = [a + (b \times \text{leadtime})] \times \text{MAD}_i, \quad [\text{Eq. D-5}]$$

where a and b are constants based on the alpha factor for the NSN.

The specific formulas for demand leadtime are as follows:

$$\text{MADLT}_i = \left( 0.7 + 0.36 \times \frac{\text{ALT} + \text{PLT}_i}{30} \right) \times \text{MAD}_i, \quad [\text{Eq. D-6}]$$

for monthly VIP items (C&T alpha factor is 0.05), and

$$\text{MADLT}_i = \left( 0.57 + 0.46 \times \frac{\text{ALT} + \text{PLT}_i}{90} \right) \times \text{MAD}_i, \quad [\text{Eq. D-7}]$$

for quarterly non-VIP items (C&T alpha factor is 0.15).

where:

ALT = administrative leadtime in days (same for all NSNs in PGC)

PLT<sub>i</sub> = production leadtime in days for the specific NSN, based on the matrix delivery method and whether the NSN is an X, Y, or Z item

MAD<sub>i</sub> = mean absolute deviation in demand for the NSN (measured per month for VIP items; per quarter for non-VIP items).

### Item Essentiality (ZE)

The essentiality factor, ZE, can be used to bias the VSL equation to give more "essential" items greater safety level (all other things being equal). The larger the ZE factor, the greater the protection. In practice, DLA has not used the essentiality factor extensively, setting ZE = 1 for virtually all items.

In the C&T world, those items demanded by Recruit Training Centers (RTCs) are considered essential, and the C&T VSL model allows RTC customers to be given

more protection through the use of the essentiality factor. NSNs with a larger percent of demand from RTCs may be assigned a larger ZE factor than those with smaller RTC demand. When the essentiality option is used, the essentiality factor, ZE, is set equal to the RTC demand percentage plus 0.5. Under that option, NSNs with no RTC demand are assigned a ZE factor of 0.5 and NSNs that have a 100 percent of their demand from RTCs are assigned a ZE factor of 1.5. The other option is to treat all NSNs equally by assigning them a ZE factor equal to 1.

### **Average Requisition Size, S**

The S in Equation D-3 denotes the average requisition size for the NSN. When the S factor is used, NSNs with larger average requisition sizes receive less protection, other factors being equal. For C&T items, however, since RTCs usually submit the largest requisitions, using S in Equation D-3 would penalize RTCs. For that reason, the C&T VSL model treats S as always equal to 1.0 in Equation D-2.

### **Backorder Goal, $\beta$**

The backorder goal,  $\beta$  (beta), is entered by the user in the query session for the C&T VSL model. Beta is an estimate of the number of time-weighted unit backorders the user wishes to specify as the backorder constraint for the system of items under consideration. In practice, Beta usually serves as a control knob to adjust the VSL model to meet either a safety level investment target for the system or a supply availability rate target. The use of beta is discussed further below.

### **Constraints on VSL**

The  $VSL_i$  defined by Equations D-1 and D-2 must meet two constraints. First, if negative, the  $VSL_i$  is set to zero. Second,  $VSL_i$  must be the minimum of three values:  $VSL_i$  as computed, three standard deviations in leadtime demand, and mean leadtime demand. In months, the VSL is the minimum of:

- $VSL_i = [k(i) \times MADLT_i \times 1.25] / AMF$
- $VSL_i = [3 \times MADLT_i \times 1.25] / AMF$
- $VSL_i = [PLT_i + ALT] / 30.$

## VSL QUERY SESSION

Like the C&T simulation, the C&T VSL model starts with a query session. After turning the PC on, the user performs the steps shown in Exhibit D-1.

```
:>CD \SIM [R]  
C:>\SIM>SIMLAB [R]  
SimLab>SELECT VSL [R]  
SimLab>RUN
```

EXHIBIT D-1. STARTING THE C&T VSL MODEL

The first step in Exhibit D-1 changes the directory from the root to the SIMSCRIPT directory, the second step calls the Simlab software of SIMSCRIPT, the third step accesses the VSL model, and the fourth step runs the VSL model. If the user is already in SimLab (if Steps 1 and 2 are complete), only Steps 3 and 4 are required.

```
----- VSL ASSUMPTIONS -----  
1) NO PGC HAS MORE THAN 200 NSNs  
2) TOTAL NUMBER OF NSNs FOR ALL PGCs IS NO MORE THAN 300 NSNs  
3) THE MATRIX DELIVERY SCHEDULES HAVE INCONSISTENCIES BETWEEN THE  
   ROP PLT AND THE DELIVERY PLT THAT MAKE VSL MODEL RESULTS LESS  
   OPTIMAL FOR THE FOLLOWING CONDITIONS:  
   - IF DELIVERY METHOD IS #1  
   - IF THE NUMBER OF PGC DELIVERIES IS GREATER THAN 6  
  
4) VIP item alpha = .05, non VIP item alpha = .15 (or a & b factors  
   are .7 & .36 for VIP; .57 & .46 for non VIP, respectively
```

EXHIBIT D-2. VSL ASSUMPTIONS



Exhibit D-2 is the first screen the model displays once the C&T VSL model is running. The screen lists the key assumptions and information the user needs to properly run the model. The first two assumptions are programming constraints for the model. Assumption 1 is that no single PGC has more than 200 NSNs. This should accommodate all C&T PGCs. The next assumption addresses the system of NSNs for which VSL values are to be computed. The model can estimate a safety level across a single PGC or a number of PGCs. If the user is calculating a VSL across a number of PGCs, the total number of NSNs cannot be greater than 300. *If that is not the case, Query 9 allows the user to increase the number.*

Assumption 3 is a reminder of possible disconnects between C&T matrix delivery schedules and the assumptions of the VSL model. The matrix delivery schedules sometimes contain inconsistencies between the production leadtime (PLT) used for reorder point (ROP) calculations and the PLT used for actual delivery. For Method 1 deliveries, and when there are more than six delivery periods, ROP and delivery PLTs may disagree by several months. Under these conditions, VSL-type safety levels are less likely to be optimal.

Assumption 4 reiterates the a and b constants used in the VSL calculations, as described in Equations D-5, D-6, and D-7.

```

1)ENTER ##### NUMBER 0 TO 5 FOR THE PGC SELECTED TO RUN #####
      NAME                SERVICE    MAX NSN    PGC NUMBER
0 - DEMO PGC (MAN'S SHIRT)  ARMY      3        1672
1 - MAN'S COAT              ARMY     65        1765
2 - WOMAN'S SHIRT           AIR FORCE  21        1671
3 - WOMAN'S SKIRT           ARMY     80        1748
4 - MEN'S SHOE              ALL     113       1505
5 - MEN & WOMEN GLOVES      ALL     17        1834
6 - WANT TO ENTER AN ALTERNATE PGC NUMBER
99 - FOR ALL PGCS IN THE SSCF report (file "SSCFSIM.DAT")

```

?

#### EXHIBIT D-3. VSL QUERY 1

Query 1 (Exhibit D-3) asks the user to enter the number of the PGC for which VSL values are to be computed. The query lists the "Demo PGC" and five other PGCs that may be chosen. If any of those PGCs are selected, the model will

automatically retrieve the required SSCF input file, prepared by the "capture" program, and the Management Policy Table 11 (MPT011) input file. If the user wishes to process another PGC not in the list, a "6" should be entered. This option allows the calculation of VSLs for the collection of items within a single, multi-item PGC. If the user wishes to perform VSL calculations for a system of several PGCs, a "99" should be entered. This option computes VSLs for a collection of NSNs across PGCs. The responses "6" and "99" both generate additional screen displays.

1a) ENTER THE PGC NUMBER (NOTE: BOTH THE SSCFSIM.DAT/MOD AND THE  
MPT011.DAT/MOD FILES MUST ALREADY HAVE THIS PGC'S DATA WITHIN

?

#### EXHIBIT D-4. VSL QUERY 1a

Query 1a (Exhibit D-4) appears if the response to Query 1 is "6" (to compute the VSL for the NSNs in one PGC). The user is required to enter the PGC number of an item not in the previous list. Query 1a allows the model to run on any PGC desired; however, the SSCF input file prepared by the "capture" program, and the MPT011 input file, must have been produced and stored in the files named C:\SIMDLA\SSCFSIM.DAT and C:\SIMDLA\MPT011.DAT, respectively.

#### THE ASSUMPTIONS FOR VSL MODEL WITH MULTIPLE PGCS:

- 1) ONLY PGCS FOR VSL IN SSCF "SSCFSIM.DAT"
- 2) THOSE PGCS ARE ALSO IN MPT011 FILE (THOUGH THE MPT011  
CAN HAVE PGCS IN DIFFERENT ORDER AND CAN HAVE PGCS  
NOT INCLUDED IN THE SSCF)

#### EXHIBIT D-5. VSL ASSUMPTIONS FOR MULTIPLE PGCS

Exhibit D-5 is the screen that follows Query 1 if the response is "99" (to compute VSL values for the NSNs in a collection of PGCs). It lists some additional assumptions of a VSL for multiple PGCs. The first assumption is a reminder that all PGCs represented in the SSCF data will be processed in the VSL run. The second assumption is a reminder that the PGCs contained in the SSCF must also have the appropriate data in the MPT011 file. PGCs may appear in different order in the MPT011 file than in the SSCF file, and the MPT011 file is allowed to contain additional PGCs not represented in the SSCF data.

2) ENTER BETA OR THE BACKORDER LINES ON-HAND GOAL  
?

#### EXHIBIT D-6. VSL QUERY 2

Query 2 (Exhibit D-6) allows the user to enter the backorder goal (Beta) described earlier. This value is adjustable, as will be discussed shortly.

3) ENTER 1 FOR FURTHER INPUT SPECIFICATIONS (QUERIES 4 TO 9)  
0 FOR NO FURTHER CHANGE AND RUN  
?

#### EXHIBIT D-7. VSL QUERY 3

If a "1" is entered for Query 3 (Exhibit D-7), five additional queries concerning optional data files, maximum number of NSNs, and model assumptions will follow.

If a "0" is entered, the VSL model run will proceed and the additional queries (4 to 9) will not appear.

Queries 4, 5, and 6 determine what input files are used. The VSL model uses the same input files as the C&T simulation. The user should be sure that the two models are using the same inputs and that the responses to Queries 4, 5, and 6 for the VSL run are the same as those to Queries 9, 10, and 11 for the simulation run.

```
4) ENTER 1  FOR OPTIONAL SCF INPUT DATA
          0  FOR STANDARD SCF INPUT DATA [D]
?
```

EXHIBIT D-8. VSL QUERY 4

Query 4 (Exhibit D-8) allows the user to modify any of the input SSCF data. To modify the SSCF data, the user must first edit a copy of the file named C:\SIM\DLA\SSCFSIM.MOD. This modification is done before running the VSL model. Once the file has been edited and saved, the VSL model can be run and "1" entered in response to Query 4. If a "0" is entered, the VSL model uses the original (default) SSCF input file (C:\SIM\DLA\SSCFSIM.DAT).

```
5) ENTER 1  FOR OPTIONAL MANAGEMENT POLICY TABLE INPUT DATA (MPT011)
          0  FOR STANDARD MANAGEMENT POLICY TABLE INPUT DATA [D]
?
```

EXHIBIT D-9. VSL QUERY 5

Query 5 (Exhibit D-9) allows the user to modify any of the input data in the MPT011 file. To do so, the user must first edit a copy of the MPT011 table in the file named C:\SIMDLA\MPT011.MOD. This modification must be done before running the VSL model. Once the file has been edited and saved, the VSL model can be run and a "1" entered in response to Query 5. If a "0" is entered, the VSL model uses the original (default) MPT011 input file (C:\SIMDLA\MPT011.DAT).

6) ENTER 1 FOR OPTIONAL ASSUMPTION FILE: M1,M2,T, OPTIONS, TRACES  
0 FOR STANDARD ASSUMPTIONS [D]  
?

#### EXHIBIT D-10. VSL QUERY 6

Query 6 (Exhibit D-10) allows the user to modify model data inputs and assumptions not contained in the SSCF and MPT011 files. To change the standard assumptions, the user must first modify the file C:\SIMDLA\ASSUMP.MOD. Once the user edits and saves that file, the model can be run and a "1" entered in response to Query 6. If "0" is entered, the default assumptions are used.

7) ENTER 1 FOR ORDER QUANTITY(Q) TO CONSIDER INCREMENTAL DELIVERIES [D]  
0 FOR A Q EQUAL TO THE PROCUREMENT CYCLE x MONTHLY FORECAST  
?

#### EXHIBIT D-11. VSL QUERY 7

Query 7 (Exhibit D-11) allows the user to select one of the two methods for calculating order quantities (Q) discussed earlier. If a "1" is entered, a Q that considers incremental deliveries is used based upon the matrix delivery method and the type of item. If a "0" is entered, a Q that assumes clumped deliveries is used no matter what the PGC matrix delivery method is.

8) ENTER 1 FOR THE ESSENTIALITY FACTOR  $ZE = \% \text{ DEMAND FOR RTC} + 0.5$   
0 FOR NO ESSENTIALITY CONSIDERATIONS OR  $ZE = 1$  [D]  
?

#### EXHIBIT D-12. VSL QUERY 8

Query 8 (Exhibit D-12) allows the user to select one of two options for the essentiality factor, ZE, discussed earlier. If a "1" is entered, the model sets the ZE factor equal to the percent of RTC demand (expressed as a fraction) plus 0.5. Under this option, ZE will have a possible range from 0.5 to 1.5. If a "0" is entered, the model sets the ZE factor for all NSNs to 1 (i.e., no essentiality weighting scheme is used).

9) ENTER 1 TO CHANGE MAXIMUM NUMBER OF NSNs IN SYSTEM (NOW AT 300)  
0 TO KEEP MAX NUMBER AT CURRENT CEILING VALUE [D]  
(NOTE: FOR MODEL TO ALLOCATE ENOUGH SPACE THIS VALUE MUST BE  
GREATER THAN OR EQUAL TO THE NO. OF NSNs FOR ALL THE PGCs)  
?

#### EXHIBIT D-13. VSL QUERY 9

Query 9 (Exhibit D-13) allows the user to increase the maximum number of NSNs that the VSL model can incorporate into its calculations. When a collection of PGCs is being processed, more NSNs may be involved than the maximum default value. If a "1" is entered, the default value can be changed in the next response; if a "0" is entered, the default value is used. The maximum number of NSNs is used by SIMSCRIPT to allocate computer memory space. The smaller the value, the faster the model runs. However, if the maximum value is less than the total number of NSNs across all PGCs, the model will have a run-time failure.

9a) ENTER THE MAXIMUM NUMBER OF NSNs YOU WANT INSTEAD  
?

EXHIBIT D-14. VSL QUERY 9a

Query 9a (Exhibit D-14) allows the user to enter a new value for the maximum number of NSNs.

```

=====
***** MODEL OPTION ASSUMPTIONS (true=1 and false=0) *****
o ALL PGCs IN SSCF IN SYSTEM VSL 0(0:FALSE= VSL within PGC for below)
1)PGC NUMBER      1672
2)BETA VALUE FOR FIRST PASS      260
4)EDITED THE SSCF DATA  0 (0:FALSE= use standard data with no change)
5)EDITED MPT011 TABLE   0 (0:FALSE= use standard data with no change)
6)EDITED ASSUMPTIONS     0 (0:FALSE = standard assumptions, no change)
7)INCREMENTAL DELIVERY Q  1 (0:FALSE= Q is order quantity)
8)ESSENTIALITY FACTOR ZE 1(0:FALSE ZE = 1, else ZE = %RTC demand + 0.5)
9)MAXIMUM SYSTEM NSNs    300  MAXIMUM NSNs IN ANY PGC 200

```

EXHIBIT D-15. VSL MODEL SETTINGS

The screen in Exhibit D-15 appears at the end of the VSL model query session. It lists the responses to the VSL queries. The VSL model will then run, unless a "CTRL" and a "C" are pressed simultaneously.

```

===== FINAL SUMMARY RESULTS FOR THE SYSTEM =====
<BACKORDERS-EBO> <AVAILABILITY> <COST IN 1000 DOLLARS > DEMAND
<BETA      MODEL> <% FILL RATE > < VSL      FSL      MADLT >AMF/1000
260.00      283.34      99.353      972.      686.      357.      21.
ENTER NEW BETA (TO STOP ENTER 0)0
?
```

#### EXHIBIT D-16. C&T VSL MODEL OUTPUT

Once the model has run, the screen in Exhibit D-16 appears. It displays aggregate information for the system of NSNs: the unit backorder goal (beta); an analytically computed estimate for time-weighted unit backorders; the demand-weighted unit supply availability; the total investment in variable safety level; the investment in fixed safety level (based on the product of the input SSCF values for fixed safety level in months times AMF times unit price); the product of cost and MADLT summed over all NSNs; and the average monthly demand in thousands of units. (The beta constraint and model-computed expected backorders will generally be different as a result of VSL constraints. They will agree only when the computed  $VSL_i$  value applies for every NSN in the collection. It is in this sense that the beta constraint is a control knob.)

At this point in the model run, the user may enter a new beta value and run the model again to reach either an investment target or a performance target. For example, the model can be used to develop a VSL mix in which the total investment in VSL equals the total investment in fixed safety levels. An increase in beta will cause the safety level investment to decrease; a decrease in beta will cause investment to increase. With a small number of iterations, the two safety-level investments can be made to agree. The user may also adjust beta to meet a system supply availability target or system backorder target. For each new beta the user



enters, the entire VSL equation is recalculated and the table in Exhibit D-16 is displayed. Once desired results are achieved, a "0" may be entered for beta, and the iterative process will stop. The entire model run including iterations generally takes no longer than 5 or 10 minutes, even for a large number of NSNs across several PGCs.

ENTER THE DIRECTORY WHERE YOU WANT THE VSL VALUES (IN MONTHS) FILE  
TO BE STORED:  
0 TO PLACE THE FILE DIRECTLY INTO THE SIMULATION DIRECTORY  
SO THAT THE SIMULATION MODEL WILL AUTOMATICALLY USE THE VSL.  
1 TO PLACE THE FILE IN THIS DIRECTORY SO THAT IT WILL NOT  
OVERWRITE AND DESTROY THE EXISTING VSL INFORMATION.  
?

#### EXHIBIT D-17. STORING THE VSL FILE

The query in Exhibit D-17 allows the user to store VSL values generated by the C&T VSL model in one of two locations. VSL values are those from the last iteration of the model. Exhibit D-18 displays the VSL values expressed in months of demand. If a "0" is entered, VSL values will be stored in a file that the simulation can automatically access, C:\SIMDLA\VSL.DAT. Any VSL information placed in this file will overwrite information previously placed in the file. If a "1" is entered, the model will store the VSL results in the current directory, C:\SIM\VSL\VSL.DAT, which can then be copied to the simulation directory if the user wants the information used in the simulation.

\*\*\*\*\*  
VSL DATA BY PGC AND NSN IN MONTHS  
\*\*\*\*\*

P PGC	1765	PGC NAME	COAT,MAN'S	PGC	1 OUT OF	5 SYSTEM PGCs
NSN	VSL(MONTHS)	NIIN	NSNs WITHIN PGC	65		
1	10.2950	011056063				
2	8.7782	011056064				
3	7.6373	011056065				
:	:	:				
:	:	:				
65	2.5100	011056127				

P PGC	1671	PGC NAME	SHIRT,WOMAN'S	PGC	2 OUT OF	5 SYSTEM PGCs
NSN	VSL(MONTHS)	NIIN	NSNs WITHIN PGC	21		
66	15.7000	010676705				
67	15.7000	010676706				
68	15.7000	010676707				
:	:	:				
:	:	:				

EXHIBIT D-18. VSL OUTPUT FILE FOR SIMULATION

### VSL TRACE INFORMATION

Besides the file of VSL values, the VSL model produces a trace file that lists the key variables calculated for each NSN. The trace information is stored in the file C:\SIM\VSL\VSLOUT.DAT. The trace information also includes the input information from the SSCF and MPT011 input files. The trace file displays the following information by NSN for every NSN processed: backorders, supply availability, MADLT, k, VSL in months, demands per year, cost, order quantity (Q), and essentiality factor (ZE).

## **APPENDIX E**

### **DYNAMIC GRAPHICS**

Computer models are often unused or misused because of the difficulty in explaining hundreds of lines of code and stacks of computer output. The combination of dynamic graphics and variable switches in the clothing and textiles (C&T) simulation offers a powerful tool for presenting simulation results in understandable form to people who need to know — whether they are programmers who must check the code, users who must learn to operate the model, or decision makers who must act on its results.

This appendix describes features of dynamic graphics and their use. It also addresses the use of simple switches that allow key variables to be held constant or varied over time. By observing the effect of different variables dynamically affecting the system over time, analysts and managers can better understand how their system — and their simulation — works.

#### **FEATURES OF DYNAMIC GRAPHICS**

Dynamic graphics are available with most personal computer (PC)-based simulation packages. The C&T simulation is programmed in PC SIMSCRIPT II.5, which offers dynamic graphics features.

In a dynamic graphic plot, information is plotted as the model actually runs. In presentations, the live aspect of plotting actual results over simulated time gives the model more credibility and interest than simply showing hard copy of a stationary plot generated earlier.

Another useful feature of dynamic plotting is the automatic adjustment of the time axis, which yields a scrolling effect as the simulation proceeds in time. With scrolling, it is possible to observe 30 years of simulated activity in chunks (e.g., 3 years at a time). The scrolling feature helps in identifying important events that may occur only rarely.

Dynamic graphics in PC SIMSCRIPT also allow the user to change the speed of a plot, plot several variables on the same set of axes, generate several plots with different axes on the same screen, or display several virtual screens as the simulation runs.

User who do not want to watch a long simulation can capture information in an external process file. That file can then be played back in a fast forward mode that takes only seconds to read and plot. (This feature can be added to the C&T simulation with a small amount of additional programming.)

Graphics software in PC SIMSCRIPT is also equipped to automatically rescale the vertical axis, as the dependent variable fluctuates in relative size. This software eliminates the need to specify the bounds of a plot before it is generated.

Dynamic graphics is sometimes combined with simulation animation, which involves the use of icons, pictures, and cartoon-like effects. Animation effects are not included in the C&T simulation system at this time primarily because dynamic plots are sufficient to communicate what goes on in the simulation.

Although this appendix discusses only dynamic graphic plots, other dynamic graphics – histograms, bar charts, pie charts, and clocks – are available in PC SIMSCRIPT.

## **SWITCHES**

Even with dynamic graphics, a plot that moves randomly up and down on the screen may give little insight into a model. To help isolate the effect of different variables, the C&T simulation has "switches" that, when turned off, hold pertinent variables constant, and when turned on, allow variables to change over time based on given distributions.

Demand and leadtime variables are the key random variables in an inventory system. The demand variable reflects the behavior of customers, and the leadtime variable reflects the behavior of suppliers. The two key switches in the C&T model are for demand and leadtime variation.

## EXAMPLE

The example discussed here illustrates dynamic graphics plotting and the use of switches. We use actual data for three different sizes of men's shirts, labeled NSN 1, NSN 2, and NSN 3 (NSN = National Stock Number).

We generate dynamic plots of the net stock on hand over time for each shirt. We illustrate three passes of the model, with all passes identical except for a change in switch settings. (In particular, the second and third passes, in which variability is introduced, employ the same random seeds as the first pass.) For those passes, none of the matrix delivery schedules are used so the entire order is received at one time.

### First Pass: Deterministic – No Variability

Figure E-1 is a snapshot of the graphic output of the model in the first pass. In this pass, customer demand equals the monthly forecast and supplier leadtimes are constant over time. The horizontal axis denotes time, from Day 1 to Day 1,080 (about 3 years). The vertical axis denotes net stock on hand in thousands of shirts. Positive stock represents on-hand inventory, while negative stock represents backorders (unfilled, outstanding customer demands).

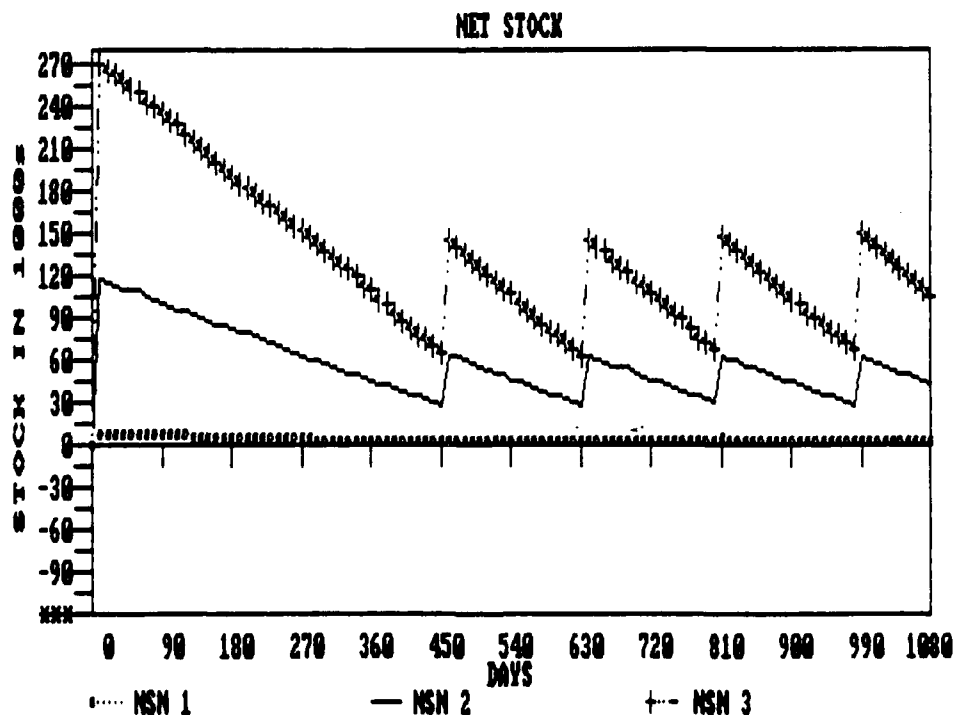


FIG. E-1. FIRST PASS: DETERMINISTIC – NO VARIABILITY

The deterministic pass is useful for observing basic features, such as leadtime and order quantity. On Day 1, a replenishment order for shirts is placed with a supplier. (The simulation starts with on-hand stocks for all three items at the reorder point.) The entire corresponding shipment arrives a leadtime (450 days) later. As shown in Figure E-1, stocks are drawn down (demands filled) until the first replenishment shipment is received on Day 450. At that time, stock levels for all three items increase by an order quantity. The order quantity for Army men's shirts is 6 months of demand. After the first shipment is received, the 6-month procurement cycle of stock is drawn down and the next shipment arrives. Repeating this pattern, we obtain the familiar sawtooth curve of inventory theory.

Figure E-1 also illustrates a simple example of a warm-up period (the time from Day 1 to Day 450), as well as steady-state conditions (from Day 450 onward).

### **Second Pass: Demand Variability**

Figure E-2 is a snapshot of the second pass of the model, with all variables the same, except that the demand variability switch has been activated. As shown in Figure E-2, the drawdown of stock is no longer linear. Also, orders no longer arrive at precise 6-month intervals (as was the case in the first pass). This is because reorder points are being reached either earlier or later as demands vary. [We have not yet introduced leadtime variability, however. Once placed, orders arrive an exact leadtime (450 days) after being ordered.]

In the second pass, actual demand exceeds forecasted demand by enough to cause backorders to occur in the third year of simulated time (between Day 720 and Day 1,080).

### **Third Pass: Demand and Leadtime Variability**

Figure E-3 is a snapshot of the third pass. This pass is identical to the second, except that the leadtime switch has now been activated. With variable leadtimes, replenishment shipments from suppliers can arrive sooner or later than the expected leadtime of 450 days.

As shown in Figure E-3, the first two shipments arrive later than expected — on Day 570 and Day 810. In the previous pass, these two shipments arrived on Day 450 and Day 580, respectively. Because of these delays, stock levels

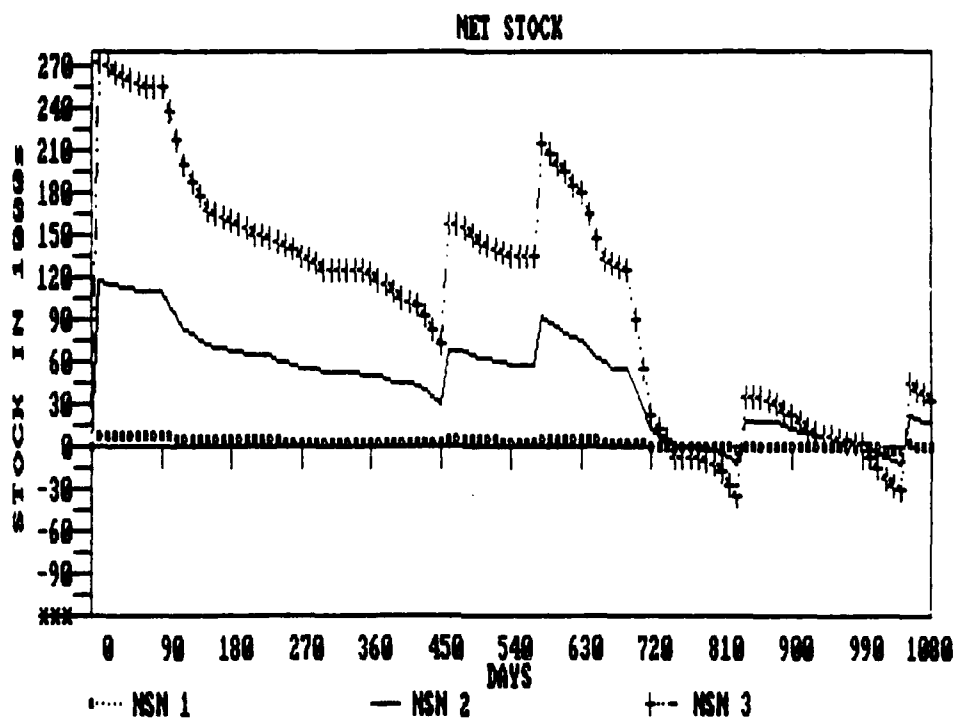


FIG. E-2. SECOND PASS: DEMAND VARIABILITY

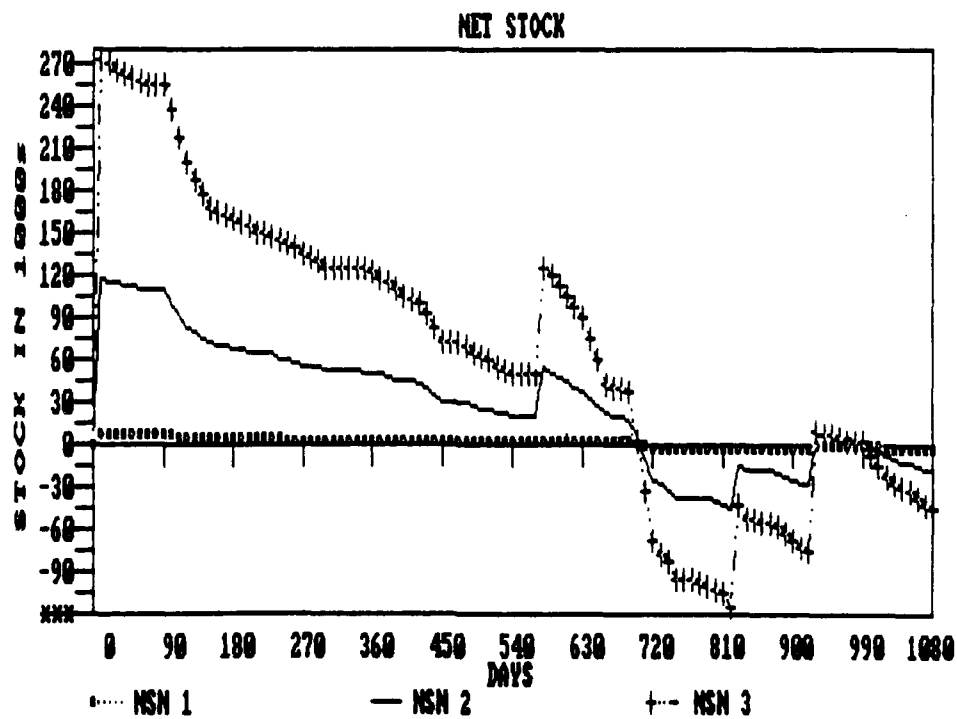


FIG. E-3. THIRD PASS: DEMAND AND LEADTIME VARIABILITY

are insufficient to meet demand and more backorders occur than in the previous pass.

To demonstrate scrolling, the third pass of the model run lasts an additional year. At the end of the third year, the model readjusts the horizontal time axis, dropping the first 540 days and adding an additional 540 days to make room for the fourth year. Figure E-4 shows final results after the model has scrolled forward.

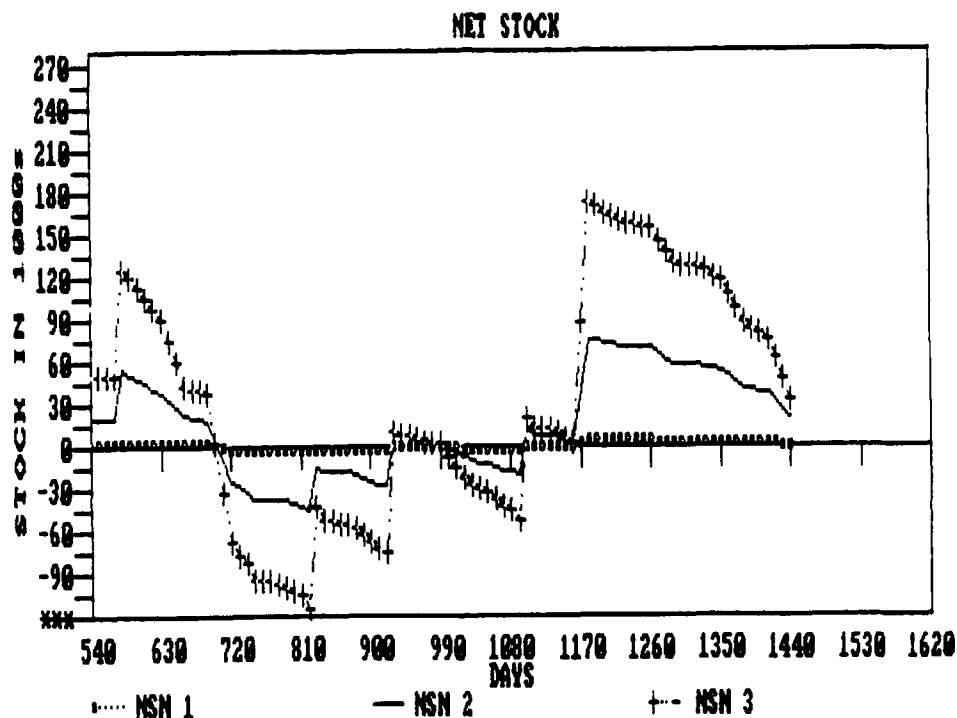


FIG. E-4. THIRD PASS CONTINUED: 4-YEAR RUN

## CONCLUSIONS

The features and flexibility of dynamic plots make it easy to observe key variables over time and to determine whether the model is working as desired. Graphics also help isolate driving conditions for further examination. With dynamic graphics, decision makers can better understand important simulation features, such as the warm-up period, variance, and the meaning of steady-state results. They can also see whether the key aspects of their business have been incorporated and are correctly modeled.



Once the user is satisfied that the simulation is running as intended, the dynamic graphics feature can be shut off. The simulation runs approximately 10 percent faster without dynamic graphics. Dynamic graphics are automatically shut off if a long run for final results is requested in the query session.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD 4 253 714

## REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified			1b. RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION / AVAILABILITY OF REPORT "A" Approved for public release; distribution unlimited.	
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE				
4. PERFORMING ORGANIZATION REPORT NUMBER(S) LMI-DL703R1			5. MONITORING ORGANIZATION REPORT NUMBER(S)	
6a. NAME OF PERFORMING ORGANIZATION Logistics Management Institute		6b. OFFICE SYMBOL (if applicable)		7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) 6400 Goldsboro Road Bethesda, Maryland 20817-5886			7b. ADDRESS (City, State, and ZIP Code)	
8a. NAME OF FUNDING / SPONSORING ORGANIZATION Headquarters, Defense Logistics Agency		8b. OFFICE SYMBOL (if applicable) HQ DLA-LOP		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER MDA903-85-C-0139
8c. ADDRESS (City, State, and ZIP Code) Cameron Station, Room 3B330 Alexandria, VA 22304-6100			10. SOURCE OF FUNDING NUMBERS	
			PROGRAM ELEMENT NO.	PROJECT NO.
			TASK NO.	WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification) Simulating Clothing and Textile Operations at the Defense Logistics Agency - Volume I: Narrative Description				
12. PERSONAL AUTHOR(S) Robert C. Kline, Christopher H. Hanks				
13a. TYPE OF REPORT Permanent		13b. TIME COVERED FROM _____ TO _____		14. DATE OF REPORT (Year, Month, Day) January 1989
15. PAGE COUNT 156				
16. SUPPLEMENTARY NOTATION				
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB-GROUP		
			Clothing and textiles, inventory, inventory management, Program Oriented Items, safety level, simulation, supply, supply management, variable safety level	
19. ABSTRACT (Continue on reverse if necessary and identify by block number)				
<p>This report provides a narrative description (Volume I) and PC SIMSCRIPT II.5 source code (Volume II) for a PC-based simulation of wholesale inventory management of clothing and textile (C&amp;T) items as practiced at the Defense Logistics Agency's Clothing and Textiles Directorate, Defense Personnel Support Center, Philadelphia, Pennsylvania. The C&amp;T simulation system includes a simulation model, a SIMSCRIPT program for preparation of input data, and an analytic variable safety level (VSL) model (also programmed in SIMSCRIPT) for computation of C&amp;T VSLs. Simulated functions include demand forecasting (both program-oriented and historical-demand-based); C&amp;T inventory control (the setting of quantitative levels, e.g., reorder point, procurement cycle quantity, acquisition objective); customer demand ("customers" being DoD retail supply points); and supplier responsiveness (leadtime variability).</p>				
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22a. NAME OF RESPONSIBLE INDIVIDUAL			22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL